APPENDIX A: MARINE AND LARGE ESTUARINE ENVIRONMENT

TABLE OF CONTENTS

Chinook Salmon and Steelhead in the Marine Environment

Because adult Chinook salmon and steelhead spend the majority of their lives at sea, evaluating marine distribution and associated current conditions and threats is a necessary component for recovery planning. For the California Coastal (CC) Chinook salmon Evolutionarily Significant Unit (ESU) and Central California Coast (CCC) and Northern California (NC) steelhead Distinct Population Segments (DPSs) this evaluation is challenging because information regarding the migration patterns and ecology of salmonids in the marine environment is primarily focused on commercial (non-listed) fisheries.

CC Chinook salmon originate in coastal watersheds from south of the Klamath River (exclusive) to the Russian River (inclusive) (70 FR 37160; June 28, 2005). Along the Pacific coast of North America, Chinook salmon are typically encountered along the continental shelf in the broad region of coast where they originated (Quinn 2005). Based on coded wire tag (CWT) recoveries and genetic stock identification (GSI) in ocean fisheries, marine distribution of CC Chinook salmon is spatially centered between the marine distributions of Klamath River fall-run Chinook salmon (KRFC) and Central Valley fall-run Chinook salmon (CVFR) (Weitkamp 2010; O'Farrell *et al.* 2012). KRFC marine distribution is generally between Point Arena in northern California and Cape Falcon in Oregon (CDFG 2001). Satterthwaite *et al.* (2014) found CC Chinook salmon were most commonly encountered in coastal areas around Fort Bragg during August and September of 2010 and August of 2011 but generally followed the same distribution of KRFC during other sampling periods.

CCC steelhead originate in coastal watersheds from the Russian River (inclusive) to Aptos Creek (inclusive), including tributaries of the San Francisco and San Pablo Bays eastward to Chipps Island (50 CFR 223.102(e)). NC steelhead originate in coastal watersheds from Redwood Creek (inclusive) to the Gualala River (inclusive) (50 CFR 223.102(e)). Bycatch of steelhead in commercial and recreational fisheries off the California coast is extremely rare and information regarding their marine distribution is limited. The marine range of steelhead originating in California may not extend as far west into the Pacific Ocean as steelhead originating north of the Columbia River Basin (Burgner *et al.* 1992). In general, however, marine distribution of steelhead may still be much broader than Chinook salmon (Quinn 2005).

In summary, CC Chinook salmon are encountered in marine waters along the broad region of coast where they originated or from the Southern Oregon Coast through the Central California Coast (Satterthwaite *et al.* 2014). This latitudinal marine distribution pattern holds true for coho salmon (Weitkamp and Neely 2002) and presumably other anadromous salmonids that utilize the California Current ecosystem, such as CCC and NC steelhead. Therefore, CCC and NC steelhead are likely to range from the Southern Oregon Coast through the Central California Coast, and possibly further north and offshore than Chinook salmon from similar areas of origin.

Two general lifestages of Chinook salmon and steelhead occupy the marine environment; juveniles and adults. Juvenile Chinook salmon are typically located closer to shore than adults. There is overlap, however, in marine habitat used by juvenile and adult lifestages as adult Chinook salmon stage in nearshore areas before entering freshwater to spawn. At times, adult and juvenile steelhead may also occupy the same habitat in the marine environment. Juvenile steelhead may rapidly move offshore after entering the ocean, or remain close to shore (*e.g.* 'half-pounders') for their entire ocean residency (Quinn 2005). Furthermore, adult steelhead may pass through or stage in nearshore areas both during migration to freshwater spawning habitats and, in some cases, following ocean reentry after spawning. Therefore, in the following discussion, current conditions and threats specific to lifestage will be identified where appropriate.

CURRENT CONDITIONS - MARINE

In this section, "current conditions" pertain to existing habitat and population conditions that affect CC Chinook salmon and CCC and NC steelhead marine survival. Important conditions affecting CC Chinook salmon and CCC and NC steelhead include: (1) quantity and/or quality of prey; (2) reduced population size; and (3) reduced genetic and life history diversity. Ocean conditions and associated prey quantity and quality are believed to have a large influence on juvenile and adult salmonid survival (Peterson *et al.* 2014). The following is a more thorough discussion of current conditions affecting CC Chinook salmon and CCC and NC steelhead in the marine environment.

PREY QUANTITY AND QUALITY

Oceanographic conditions (*e.g.,* upwelling, sea-surface temperatures, El Nino, Pacific Decadal Oscillation, *etc*.) are major factors influencing coastal productivity and salmonid prey quantity and quality in the marine environment (Peterson *et al*. 2014). The location, timing, and strength of coastal upwelling events are important factors that influence the availability and type of prey for salmonid species.[1] Coastal upwelling typically occurs off the U.S. West Coast during spring and summer months, and involves the wind-driven transport of cooler, more saline, and nutrient-rich waters from deeper depths to the surface and toward shore. Transport of this nutrient-rich water upward to the photic zone near the surface triggers the formation of large phytoplankton blooms. Phytoplankton (diatoms, dinoflagellates, etc.) form the base of the marine food chain and are eaten by zooplankton (copepods, fish larvae, etc.); zooplankton, in turn, are preyed upon heavily by forage fish species (anchovy, smelt, herring, etc.) and juvenile salmonids.

Many studies have shown that the strength and timing of upwelling events affects salmonid survival by influencing the overall abundance and spatial distribution of plankton within the nearshore marine environment. For example, Gunsolus (1978) and Nickelson (1986) correlated salmonid marine survival with the strength and/or timing of marine upwelling. Additionally, Cury and Roy (1989) demonstrated a relationship between upwelling and recruitment of several pelagic forage fishes in the Pacific Ocean.

Sea surface temperatures, upwelling and chlorophyll levels can be used to help predict future forage species abundance, and corollary salmonid production (CDFW 2014). For example, Pacific herring recruitment in the Bering Sea and northeast Pacific was accurately forecasted

[1] A description of upwelling along the coastal Pacific Northwest region and the California Current marine ecosystem is provided in more detail in Peterson *et al.* (2014).

based on the air and sea surface temperatures when spawning occurred (Williams and Quinn II 2000), and many Pacific herring also starved during a winter of low zooplankton abundance in Prince William Sound, Alaska (Cooney *et al.* 2001). Juvenile Chinook salmon and steelhead primarily feed on pelagic marine invertebrates, whose production is also dependent on upwelling levels, and transition to larger prey (predominantly forage fish) as they increase in size (Moyle 2002). In short, coastal upwelling can produce optimal conditions for juvenile and adult salmonid growth and survival, largely through food chain effects from phytoplankton to forage fish.

EL NIÑO

El Niño Southern Oscillation (hereafter "El Nino") is a semi-periodic climatic event that can create warm, nutrient-poor ocean conditions unfavorable for salmonid growth and survival in California's nearshore marine environment.[2] An El Nino event is generated by atmospheric conditions in equatorial waters, and generally results in warm, nutrient-poor water transported from equatorial waters north along the western coasts of Central America, Mexico, and the United States. Depending on the strength of the El Nino event, California's nearshore marine environment typically experiences an increase in sea surface temperatures, substantial reductions in coastal upwelling, and temporary northward migrations of tropical and subtropical marine species into the marine waters off California that normally exhibit temperate oceanic conditions. Since the early 1980s, the California Current has experienced an increased frequency of El Niño events, with large El Niño events occurring every 5-6 years: 1976-77, 1982-83, 1986-87, 1991-92, 1997-98, 2002-03 and again in 2009-10. A higher frequency of El Niño events appears to be a characteristic of the extended periods of warm ocean conditions. These conditions can be associated with reduced salmonid prey quantity and quality in the marine environment, negatively affecting salmonid populations. For example, the 1982-83 El Niño resulted in decreased adult salmonid survival and was correlated with the lowest average size of coho and Chinook salmon in Oregon's commercial fisheries since these statistics were first

[2] For more detail about El Nino and the northern California Current, please visit: http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/cb-mei.cfm

recorded in 1952 (Johnson 1988). It remains uncertain, however, how relatively recent changes in El Nino frequency and intensity affect salmonid prey resources over broad temporal scales.

PACIFIC DECADAL OSCILLATION

Pacific Decadal Oscillation (PDO) is generated by atmospheric conditions in the North Pacific Ocean, and is another important factor that affects oceanographic conditions for salmonid growth and survival in California, Oregon and Washington.[3] The PDO is a climatic phenomenon that creates cool or warm sea surface temperatures off the west coast of the U.S. for prolonged periods, sometimes decades at a time. These cool or warm phases are created by the predominant direction of winter winds in the North Pacific, with winds blowing from the southwest causing warmer conditions in the northern California Current off the U.S. West Coast. The California Current warms during these conditions due to onshore transport of warm waters that normally lie far offshore. In contrast, when prevailing winds blow from the north, upwelling occurs both in the open ocean and at the coast leading to cooler, nutrient-rich conditions in the California Current.3

Increased salmon abundance has been linked to cool phases of the PDO, and decreases in salmon returns have been associated with warm phases of the PDO. For example, the cool PDO experienced between 1947-1976 correlates with high returns of Chinook and coho salmon in Oregon rivers (Mantua *et al.* 1997). Salmon numbers declined steadily in the years that followed during a warm phase from 1977-1998.[4]

NOAA's Northwest Fisheries Science Center (NWFSC) accurately predicted salmon runs in Oregon based on PDO phases, and the approximate two-year delay between juveniles entering the ocean and adult returns. Adult spring-run Chinook salmon runs declined, beginning with

[3] For more detail on the Pacific Decadal Oscillation, please visit http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm

[4] Note that during the 22–year cool phase of the PDO (1955 to 1977), below–average counts of spring Chinook salmon at Bonneville Dam were seen in only 5 years (1956, 1958-60, and 1965). In contrast, below–average counts were common from 1977 to 1998 when the PDO was in a warm phase; below–average counts were observed in 16 of these 21 years. For figures, please visit: http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm

fish that entered the sea in 2003 and experienced poor conditions associated with the warm PDO phase in that year. This decline continued for 3 years, until 2008 and 2009, when returns began to increase, as predicted based on ocean conditions during 2006–2007.[5] Also as predicted, the third highest returns on record occurred in 2010, from juvenile Chinook salmon that entered the ocean in spring 2008, a strongly negative/cool phase.[6]

Copepod Biodiversity

In addition, salmonid production is also influenced by the species richness, or diversity, of sub-arctic zooplankton associated with upwelling events. Sub-arctic copepods, larger in size and higher in fat content than sub-tropical copepods, promote higher growth and survival of juvenile salmonids and forage fish (Peterson *et al.* 2006). Peterson *et al.* (2006) developed the Copepod Biodiversity Index, a useful tool that helps to predict salmonid year-class strength based on the species and inferred source (i.e., sub-arctic or sub-tropical) of copepods present over the continental shelf.[7] Generally, in the northern California Current, during cool PDO phases the less diverse but more productive subarctic copepod suite of species is observed, with the more diverse but less productive subtropical copepod suite of species observed during warm phases.

In summary, with all other factors that affect salmonid growth and survival being equal, salmonids generally thrive in the marine environment during coastal upwelling, cool PDO phases, and years without a strong El Nino event. With the possibility that the frequency of adverse oceanographic conditions have increased over time, reduction of prey quantity and quality is considered a medium to high stressor to CC Chinook salmon and CCC and NC steelhead.

[5] For more details, please visit http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/g-forecast.cfm
[6] For more details, please visit http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm

[7] For more information about the Copepod Biodiversity Index, please visit http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ea-copepod-biodiversity.cfm

Population size

Reduced population size has increased Chinook salmon and steelhead vulnerability to threats in the marine environment. CC Chinook salmon and CCC and NC steelhead have substantially reduced populations throughout their range, including marine habitats. Reduced population size in salmonids is a result, in part, of direct mortality in marine environments (*e.g.*, fishery-related mortality, predation, *etc.*). Freshwater distribution of salmonids has also decreased with reductions in population size and diversity. With decreased freshwater distribution and population size, threats such as marine mammal predation around lagoons are more likely to involve a larger proportion of the ESU or DPS. Therefore, reduced population size is uniformly considered a medium to high stressor.

Genetic and life history diversity

Loss of life history and genetic diversity has reduced the ability of CC Chinook salmon and CCC and NC steelhead to take advantage of ocean conditions that may be changing on a variety of temporal and spatial scales. A number of life history and genetic traits influence salmonid growth and survival, such as timing of migration, size and age at outmigration, and migration patterns (Quinn 2005). Diversity in salmonid life history and genetic traits increase resiliency to varied threats, and are necessary to persist or thrive through varying ocean conditions. Overall, CC Chinook salmon and CCC and NC steelhead have experienced a net loss of diversity (Good *et al*. 2005). As a result, Chinook salmon and steelhead may have lost a significant degree of resiliency to varying ocean conditions and are at a greater risk of extinction.

The timing of ocean entry can affect the likelihood of salmonid survival in the marine environment (Quinn 2005). Beamish *et al*. (2010) documented a higher survival in Chinook and sockeye salmon with relatively late ocean entry, likely due to the higher probability that upwelling is ongoing or has occurred recently. Duffy (2009) found that marine survival of juvenile Chinook salmon was related to growth and associated prey availability during spring and summer. Although the timing of ocean entry and associated seasonal productivity appears critical to salmonid survival, peak ocean upwelling and productivity is quite variable. Between

1967 and 2005, the date of spring transition (the start of upwelling), at 39º North latitude, has varied from January 1 to early April (Bograd *et al.* 2009). Salmonids have responded to these environmental changes by maintaining variation in several life history characteristics, including timing of ocean entry. Spreading outmigration timing across a temporally variable ocean environment may hedge against year class failure.

Varying size and age of outmigrating Chinook salmon and steelhead are important factors that can hinder or improve a population's ability to respond to environmental change and persist in the marine system. The relationship between size and survival of juvenile salmonids has been documented in a number of studies (reviewed in Quinn 2005). With the exception of fisheries-related mortality, size-selective mortality in the ocean (mainly through predation) suggests larger individuals likely experience higher survival rates than smaller individuals (Holtby *et al.* 1990; Bond *et al.* 2008; Duffy 2009). Exceptions to this pattern may occur if the freshwater or estuarine environment's various physical and biological conditions are severely degraded. It may be worth the risk of predation to outmigrate at a smaller size to take advantage of increased growth opportunities at sea. In addition, some individual salmonids may be larger than average at an earlier age due to their genetic disposition, and this may translate to increased growth and survival at sea for those individuals (Beamish *et al.* 2004).

Once Chinook salmon reach the ocean, they display a range of different migratory patterns depending on life history and origin (Weitkamp 2010). Broad ocean distribution allows salmonids to take advantage of numerous feeding opportunities and spreads the risk of isolated mortality events (such as predation, fisheries impacts, or ocean conditions). Chinook salmon and steelhead have the most diverse life histories of Pacific salmonids. For example, Chinook salmon may return to their natal streams to spawn either after approximately 1.5 years at sea (jacks) or, more typically, after 2 years or more at sea as larger adults. Steelhead may return to their natal streams either after a few months at sea (half-pounders) or after multiple years at sea as larger adults. Maintaining diversity in ocean residence time prior to spawning ensures some genetic overlap between brood years and is thought to increase the overall productivity and resiliency of the population. Also important to the overall health and resilience in salmonids is the presence of strays, which do not return to their natal spawning grounds and consequently help to colonize new spawning areas and re-establish diminished populations.

Genetic diversity and varied life history strategies in salmonids result from random events like genetic drift and evolutionary adaptations to uncertain environments (*e.g.*, see ISG 2000). The CC Chinook salmon ESU and CCC and NC steelhead DPSs have lost much of their historical life history and genetic diversity due to reduced population size, loss of connectivity between populations and genetic dilution from past hatchery practices using non-native stocks (Good *et al*. 2005). The remnant life history characteristics likely limit extant populations from taking full advantage of the range of ocean conditions, diminishing overall productivity. Because of the importance of maintaining a diverse genetic pool and set of life history strategies to the survival and growth of Chinook salmon and steelhead at sea, the loss of these traits is considered a medium to high stressor.

THREATS - MARINE

In this section, "threats" pertain to ongoing or future factors that affect CC Chinook salmon and CCC and NC steelhead marine survival. These threats generally include, but are not limited to, fisheries; transportation; habitat modification; invasive species; disease, predation, and competition; noise; and mariculture. Climate change could also be categorized as a threat through its influence on ocean productivity and marine survival, but is discussed separately in Appendix B.

FISHERIES

Fisheries-related mortality is separated into the following categories: (1) direct mortality (e.g., harvest); (2) indirect mortality (e.g., mortality of under-sized fish following release); and (3) bycatch. The harvest of steelhead in the following fisheries is prohibited and bycatch is extremely rare (71 FR 834; January 4, 2006). Therefore, the threat of fisheries to the recovery of CCC and NC steelhead is considered low and will not be discussed further.

Direct mortality in Chinook salmon fisheries

All marine fishing occurring within three nautical miles off the coast of California is managed by the California Fish and Game Commission. NMFS, in coordination with the Pacific Fishery Management Council (PFMC), manages Chinook salmon fisheries in the Federal Economic Exclusion Zone (EEZ; 3 to 200 nautical miles offshore of California). State and federal fishing regulations are coordinated and harvest of Chinook salmon is permitted subject to seasonal closures, area and gear restrictions, and bag and size limits (78 FR 25865, May 3, 2013; CDFW 2013).

No quantitative population estimate or exploitation rate for CC Chinook salmon exists at this time. Harvest of marked and unmarked Chinook salmon is permitted in commercial and recreational fisheries. A portion of hatchery Chinook salmon are marked (*e.g.*, Klamath River Fall-run Chinook and Central Valley Fall-run Chinook) and analyzed following capture to evaluate effectiveness of fishing regulations, however, a large portion of hatchery and wild Chinook salmon are unmarked (including CC Chinook salmon). Without analysis of tissue samples (*e.g.*, Genetic Stock Identification, otolith microchemistry, *etc.*), the origin and composition of unmarked populations are unknown. Thus, the specific level of CC Chinook salmon caught in commercial and recreational Chinook salmon fisheries remains relatively unknown (O'Farrell *et al.* 2012).

Klamath River Fall-run Chinook (KRFC) harvest restrictions are used to limit incidental harvest of CC Chinook salmon to a level that allows for persistence of CC Chinook at low abundances (NMFS 2000). In addition, seasonal and area restrictions are implemented to achieve a preseason-predicted KRFC age-4 ocean harvest rate of no greater than 16 percent (78 FR 25865; May 3, 2013). The area between Humboldt South Jetty and Horse Mountain has been closed to commercial salmon fishing since the early 1990s, largely for the purpose of protecting CC Chinook populations (O’Farrell *et al.* 2012). These restrictions reduce the catch of CC Chinook salmon that share common ocean ranges with KRFC (O’Farrell *et al.* 2012).

In ocean salmon fisheries, wild CC Chinook salmon are most commonly contacted from the Oregon state border to San Francisco (Weitkamp 2010; Satterthwaite *et al.* 2014). Genetic Stock Identification of Chinook salmon from the Fort Bragg area in 2010 and 2011 indicated catch per unit effort was similar for CC Chinook salmon and KRFC in the early season and higher for CC Chinook salmon than KRFC in July and August (Satterthwaite *et al*. 2014). Although CC Chinook harvest does occur in northern California, mortality levels have likely been reduced through limits to KRFC age-4 ocean harvest rates and commercial fishing area restrictions.

Indirect mortality from catch and release of undersized Chinook salmon

Ocean harvest of any undersized Chinook salmon is not permitted in California, however, indirect mortality may occur from the catch and release of undersized CC Chinook salmon. Estimated mortality of released Chinook salmon in ocean fisheries (*e.g.,* KRFC) ranges from approximately 12 to 42 percent depending on fish size, fishery, method, and location (Grover *et al.* 2002; PFMC 2007). Undersized Chinook salmon are routinely encountered in commercial and recreational fisheries and some degree of CC Chinook salmon mortality is inevitable. It is difficult to quantify the mortality of undersized CC Chinook salmon from catch and release methods because unmarked Chinook salmon that are caught could be either CC or KRFC Chinook, for example.

In addition to causing mortality to CC Chinook salmon, fisheries can indirectly reduce diversity of life history strategies and alter the population structure, especially in small populations. There is a minimum size limit for harvest of Chinook salmon off the California coast and older Chinook salmon can be removed from the population at a disproportionately higher rate. Over time this selective pressure can lead to a predominance of Chinook salmon spawning at a younger age, which could reduce the resiliency of a population to environmental variability. For example, if spawning conditions are poor for three years or more, then the persistence of a population relies solely on successful spawning of the remaining older fish. This population structure and life history effect is somewhat reduced for CC Chinook salmon because the exploitation rate is presumably lower than targeted stocks such as KRFC.

The effects of direct salmon fisheries-related mortality and indirect effects from catch and release of undersized CC Chinook salmon remain uncertain. Therefore, Chinook salmon fisheries are considered a moderate threat to the recovery of CC Chinook salmon.

Bycatch in federal non-salmon fisheries

The PFMC manages three fisheries in Federal waters potentially affecting CC Chinook salmon and CCC and NC steelhead through fishery bycatch: Groundfish, Coastal Pelagic Species (CPS), and Highly Migratory Species (HMS). The highest level of Chinook salmon bycatch occurs in the Groundfish fishery, however, NMFS evaluated the Groundfish Fishery Management Plan (FMP) in their 1999 Biological Opinion and 2006 Supplemental Biological Opinion and determined Groundfish fishery activities and implementing regulations were not likely to jeopardize the continued existence of listed salmon and steelhead (NMFS 1999; 2006).

Chinook salmon are incidentally captured in fisheries targeting CPS but at relatively low levels (PFMC 2005). Furthermore, NMFS evaluated the CPS FMP in their 2010 Biological Opinion and determined fishery activities and implementing regulations were not likely to jeopardize any endangered or threatened species under their jurisdiction.

The HMS fishery targets various species of tunas, sharks, and billfishes as well as mahi-mahi. Although all listed salmonid ESUs and DPS could occur in the area where HMS fishing occurs, there are no records indicating any instance of take of listed salmonids in any HMS fisheries. In addition, based on gear types, location of effort, and methods, it is unlikely that vessels targeting HMS would interact with salmonids (NMFS 2004). Therefore, bycatch of Chinook salmon and steelhead in federal non-salmon fisheries is considered a low threat to the recovery of CC Chinook and CCC and NC steelhead.

TRANSPORTATION

Oil spills can have significant, catastrophic effects on marine ecosystems,[8] including chronic effects and acute mortality of fishes. The effects of crude oil on pink salmon have been studied extensively since the Exxon Valdez oil spill in Prince William Sound, Alaska. Review of research on this topic showed the spill posed a low risk to pink salmon (Brannon and Maki 1996). Some researchers, however, found a reduction of growth rates of juvenile pink salmon associated with spill (Moles and Rice 1983; Willette 1996). Oil spills appear to have the greatest effect on aquatic birds and marine mammals and benthic (bottom-dwelling) organisms (Boesch *et al.* 1987). Toxic effects of crude oil have also been documented on the embryos and larvae of herring on oil-affected beaches (Hose *et al.* 1996). However, none of the equivalent life stages of Chinook salmon or steelhead occur in nearshore marine areas or the open ocean. Therefore, the direct effect of oil spills on these lifestages is likely low.

Indirect effects of crude oil on the nearshore environment include disruption of food webs and reduction in submerged aquatic vegetation. Submerged aquatic vegetation, such as kelps and eelgrass, provide habitat for some juvenile salmonids (Thorpe 1994). In some circumstances, crude oil may disrupt the marine food web by inhibiting photosynthesis in phytoplankton communities in nearshore areas (Gordon and Prouse 1973). Researchers, however, determined crude oil did not negatively affect photosynthesis in the open ocean (Gordon and Prouse 1973). The Cosco Busan heavy fuel oil spill occurred in 2007 in the San Francisco Bay and spread locally to the Pacific Ocean. Though the direct effect of this spill to salmonids is not known, marine areas utilized by CCC steelhead, CC Chinook salmon, and, presumably to a lesser degree, NC steelhead were impacted. Spills of this magnitude, however, are uncommon and the threat of transportation-related hazardous spills in marine waters to the recovery of CC Chinook salmon and CCC and NC steelhead are considered low.

[8] For more details on the effects of oil spills on marine life, see NOAA's Office of Response and Restoration website at http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants.html

HABITAT MODIFICATION

Harvest of kelp from near shore marine areas

Both bull (*Nereocystis luetkeana*) and giant (*Macrocystis pyrifera*) kelp are harvested from California waters in the area of CC Chinook, CCC and NC steelhead. California Department of Fish and Wildlife recorded an annual average of approximately 176 wet tons per year of commercial giant and bull kelp harvest for human consumption and other uses from 2010 to 2014 between Monterey Pier, Monterey County to Midway Point (north of Klamath River), Del Norte County (pers. comm. CDFW staff, March 30th, 2015). Generally the upper 2 meters of canopy are harvested, allowing the plant to continue to grow, although a large harvest can hinder reproductive potential and decrease kelp canopy habitat for juvenile rockfish, perch, and other species (Spinger *et al.* 2006). Surveys of the fish communities in kelp beds off California south of the CC Chinook salmon and CCC and NC steelhead ranges are typically focused on rockfishes rather than salmon (Paddack and Estes 2000).

Salmonids may directly or indirectly rely on kelp beds in some areas, and there is a relatively small amount of giant and bull kelp harvest within the area. In addition, kelp beds are a productive nearshore biogenic habitat that may indirectly contribute to the prey base of juvenile or returning salmonids in the area. However, at this time there is no evidence salmonids in California rely heavily on kelp beds in the nearshore marine environment. Therefore, the threat of kelp harvest in California to the recovery of CC Chinook salmon and CCC and NC steelhead is considered low.

Wave energy generation

Wave energy can be harnessed to provide electricity, and there are a small number of ongoing proposals to do so in the marine range of the CC Chinook salmon and CCC and NC steelhead[9]. The generators needed to produce this energy have the potential to impact salmonids and their marine habitat. According to the proceedings of a workshop on the ecological effects of wave energy generation in the Pacific Northwest, the electromagnetic fields and noise associated with

[9] For current proposals and more information on the Pacific Fisheries Management Council's interest in wave energy, please visit: http://www.pcouncil.org/habitat-and-communities/wave-tidal-and-offshore-wind-energy

underwater wave energy structures pose a risk to salmonids (Boehlert *et al.* 2008). Salmonids may avoid the structures as a result of the electromagnetic fields and/or noise; such avoidance could interfere with the migration of juveniles along the coast and disrupt adult spawning migrations.

Harnessed wave energy also has the potential to affect transport of zooplankton (Boehlert et al. 2008), and in doing so could indirectly impact salmonid food supply. Little data documenting the environmental effects of wave energy generation has been collected to date and there is a high degree of uncertainty regarding the potential effects to salmonids. Currently, wave energy poses a low threat to CC Chinook salmon and CCC and NC steelhead recovery since no operational projects exist at this time. However, thorough research investigating potential adverse impacts on salmonids and near shore habitat should be required before future wave energy projects are permitted.

Invasive species

Invasive species can be detrimental to salmonids, particularly in the freshwater or estuarine environments. Many invasive species have become established in freshwater and estuarine environments in California through ship hull fouling and ballast water introductions. One approach to slow the rate of non-native species introductions is the adoption of large vessel requirements to replace ballast water in the ocean far from shore before docking at any California port, where marine conditions are typically less hospitable to invasive species that inhabit estuaries (State of California 2003). In addition, the EPA's National Pollutant Discharge Elimination System Vessel General Permits limit ballast water exchange for certain non-military, non-recreational vessels in waters of the United States (USEPA 2013; 2014). Invasive euryhaline species can pose a threat to salmonids in the marine environment. For example, striped bass could potentially consume juvenile salmon, and, to a lesser degree, compete with adult salmon for forage. The majority of fish introduced in California, however, remain in freshwater and estuarine environments. Therefore, the threat of introduction of additional non-native species in the marine environment to the recovery of CC Chinook salmon and CCC and NC steelhead is considered low.

Disease, Predation, and Competition

Predation

Predation by marine mammals (principally seals and sea lions) is of concern in areas experiencing decreased or dwindling salmonid run sizes (69 FR 33102; June 14, 2004). Although salmonids appear to be a minor component of the diet of marine mammals (Scheffer and Sperry 1931; Brown and Mate 1983; Hanson 1993; Goley and Gemmer 2000; Williamson and Hillemeier 2001), focused predation during peak migration times can still involve a large component of an ESU or DPS.

Harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianus*) numbers have increased along the Pacific Coast since passage of the Marine Mammal Protection Act of 1972. At the mouth of the Russian River in western Sonoma County, Hanson (1993) found foraging behavior of California sea lions and harbor seals appeared to be coincidental with salmonid migrations. Habitat conditions within the range of CC Chinook salmon and CCC and NC steelhead can concentrate large portions of a local run in a small area (i.e., lagoon mouths). Under these types of conditions, marine mammal predation may impact a significant portion of a run, and local depletion might occur (NMFS 1997; Quinn 2005). Due to depressed population size and limited range of critical sub-populations, NMFS considers the threat of marine mammal predation on CC Chinook salmon and CCC and NC steelhead to be moderate to high.

Avian predation is not expected to constitute a significant threat to adult salmonids because of their relatively large size once in the ocean. All documented incidences of significant effects of avian predation on juvenile salmonids have occurred in estuarine areas near large nesting colonies with high avian densities. While birds are also known to feed on schools of fish in the open ocean (Scheel and Hough 1997), salmonids in the open ocean are typically large individuals in dispersed schools. Nearshore avian predation of juvenile salmonids is not well documented, but salmonids are not expected to be concentrated in these areas and predation is likely to be low. Avian predation is therefore not expected to constitute a significant threat to the recovery of CC Chinook salmon and CCC and NC steelhead in marine areas.

Management of salmonid prey and competitors

As salmonids grow in the ocean, their diet becomes more reliant on fish. Harvest of forage fish may have direct and indirect effects on salmonids. Theoretically, harvest of forage fish at some levels may reduce prey availability for higher level predators including salmonids. Forage fish also provide alternate prey sources for predators of juvenile salmonids, such as hake. Forage fish abundance was a factor in estimated juvenile Chinook salmon marine survival at the mouth of the Columbia River (Emmett and Sampson 2007). Therefore, harvest of forage fish at high levels could also have a compounding effect on salmonids as adult salmonid prey base is reduced and predators consume a greater proportion of juvenile and/or adult salmonids.

The potential impacts of the CPS fishery also apply to CC Chinook and CCC and NC steelhead, and could affect salmonids if forage was reduced to inadequate levels. However, the PFMC has adopted a conservative approach to management of CPS that reduces the likelihood of such negative effects. The need to "provide adequate forage for dependent species" is recognized as a goal and objective of the CPS FMP (PFMC 1998). A control rule is a formula used by the PFMC to determine harvest levels for each of the CPS. The CPS control rules contain measures to prevent excessive harvest, including a continual reduction in the fishing rate if biomass declines. In addition, the control rule adopted for species with significant catch levels explicitly leaves thousands of tons of CPS biomass unharvested and available to predators. No ecosystem model currently exists that can calculate the caloric needs of all predators in the ecosystem, but the amount of unharvested CPS biomass may be modified if new information becomes available. Ocean temperature is a factor in the control rule for Pacific sardine, in recognition of the effects of varying ocean conditions on fish production rates. Allowable harvest rates are automatically reduced in years of poor production. Due to the conservative control rules used to manage CPS and the preservation of a portion of the biomass for predator consumption, the CPS fishery poses a low threat to CC Chinook salmon and CCC and NC steelhead recovery.

NOISE IN THE MARINE ENVIRONMENT

Salmonids rely on sound, in part, for their survival in the marine environment. Anthropogenic noise, including increased background noise and high intensity sources, can cause behavioral change and physical injury in the form of hearing loss, tissue damage, and mortality.

High Intensity Sources

In Northern California pile driving mostly occurs in estuarine environments rather than marine and offshore environments, but may affect salmonids during such pile driving related to piers, oil rigs, offshore energy, etc. Pile driving produces a high intensity sound, which can cause behavioral alteration (Hastings and Popper 2005), tissue damage (Gaspin 1975), hearing loss frequencies (Hastings *et al.* 1996; Scholik and Yan 2001; McCauley *et al.* 2003), and even mortality in fish located in the direct vicinity of the action (Hastings 1995). There are few marine pile driving projects in Northern California that are ongoing or proposed. Due to consultations required under section 7 of the federal Endangered Species Act for actions authorized, funded, or carried out, in whole or in part, by Federal agencies, NMFS will generally consult on proposed marine or offshore projects that include pile driving in the marine environment used by CC Chinook, CCC and NC steelhead. In addition, sound attenuation technologies (e.g. bubble curtains, coffer dams) may be implemented to help minimize adverse effects to listed species and prey resources that may be present in the impact area.

Seismic air guns are used around the world in geological surveys, primarily to provide information on potential deposits of oil and gas. The air guns are towed by a boat, and the sound is projected downward, although some lateral energy as well (reviewed in Popper and Hastings 2009). Although seismic air guns have been shown to cause hearing loss in fish (McCauley *et al.* 2003), little air gun activity is expected in the area occupied by CC Chinook, CCC and NC steelhead due to the existence of current National Marine Sanctuaries in the area

(Cordell Bank, Gulf of Farallones, and Monterey), and the lack of large oil reserves in Northern California[10].

Out of the many applications for sonar used in the marine environment (fisheries, research, military, *etc.*), active sonar used by the military is perhaps the greatest concern for salmonids in the area. The majority of the concerns regarding active sonar are currently focused on adverse effects to marine mammals[11]. No mortality or tissue damage has been documented for fish (Popper and Hastings 2009), although Popper *et al.* (2007) and Halvorsen *et al.* (2006) demonstrated hearing loss to several species of fish from low frequency active sonar, including *O. mykiss* (low frequency travels further than high frequency). Adverse effects to salmonids from active sonar may be prevalent; however, more studies are needed to help identify behavioral and physical impacts from active sonar to fish and salmonids.

Underwater blasting is used for rock demolition, underwater construction, mine demolition training, military training, and demolition of unexploded marine munitions, and represents the loudest anthropogenic source of noise in the oceans with the potential for lethal injury of marine organisms (Koschinski 2011). Chemical explosions for research, construction, and military testing have been conducted in regular frequency (300 to 4,000 per month during the 1960s) (Spiess *et al.* 1968), and although air gun arrays have replaced chemical explosions for seismic exploration, they continue to be used in construction and the removal of undersea structures (Hildebrand 2004). Few projects involving underwater explosions are expected to occur in the marine environment of CC Chinook, CCC and NC steelhead, however NMFS would likely consult on projects that involve construction and the removal of undersea structures.

[10] The large oil reserves in California are located in Southern California, and extend as far north as just south of the waters off Morro Bay.
http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Resource_Evaluation/Reserves_Inventory/1999-2003-POCS_Reserves2007-012.pdf

[11] NMFS has issued regulations regarding authorizations for incidental taking of marine mammals by the U.S. Navy when it is using certain types of active sonar. For example, see 77 FR 50290, August 20, 2012

Increased Background Noise

One of the most pervasive anthropogenic ocean noises is caused by transoceanic shipping traffic (Stocker 2002). Large commercial shipping traffic (container ships, tankers, tugs and barges) emit sound underwater that may affect salmonids in the area. The west coast of the U.S. is one of the busiest routes for container shipping in the world, and the Port of Oakland in San Francisco Bay is the fifth largest container port in the U.S.[12] Smaller commercial and recreational traffic also may affect salmonids in the area, as the San Francisco Bay Area has a dense and growing human population with recreational, military, development, and research activities taking place. The greater the ship's volume, the greater its acoustic output, and with the growing capacity and number of commercial shipping vessels, the issue of noise pollution in the marine environment may escalate (Jasny *et al.* 2005). As reviewed in Popper and Hastings (2009), the sound from marine vessels may alter behavior of fish, although more studies are needed in order to determine the intensity and type of effect of vessels on salmonids.

The generators needed to produce energy from waves have the potential to create enough noise to impact salmonids and their marine habitat. According to the proceedings of a recent workshop on the ecological effects of wave energy generation in the Pacific Northwest, the electromagnetic fields and noise associated with underwater wave energy structures pose a risk to salmonids (Boehlert *et al.* 2008). Salmonids may avoid the structures as a result of the noise; such avoidance could interfere with the migration of juveniles along the coast and disrupt adult spawning migrations. More research is needed on the noise effects of large scale wave energy on salmonids and marine habitat.

Wind energy is increasingly being used as an alternative energy source, and offshore wind power has become one of the fastest growing energy technologies. Projects are currently being proposed off the U.S. west coast in or near the area of listed salmonids[13]. In addition, there are large, potentially productive wind power areas available offshore in the area of CC Chinook, CCC and NC steelhead. The potential effects on marine life of the sound generated by the

[12] For more information: http://www.portofoakland.com/maritime/factsfigures.aspx
[13] For more information, please visit: http://www.pcouncil.org/habitat-and-communities/wave-tidal-and-offshore-wind-energy/

construction and operation of wind farms need to be considered when siting wind turbines. Construction operations such as pile driving produce intense sounds that may affect fish over short durations. In addition, operation of wind farms could result in long-term increases in ambient noise, which could affect fish behavior, migration, or reproduction. More studies on the effects of wind farms on fish and salmonids are needed, particularly as new turbines are designed.

Increased ocean background noise may interfere with feeding (Wale *et al.* 2013; Voellmy *et al.* 2014), communication (Wahlberg and Westerberg 2005; Codarin *et al.* 2009), or breeding activities (Popper 2011). In addition, fish suffer from physiological or physical effects of increased underwater noise (Popper 2011).

Although there is a need for more research on the physical and behavioral effects of increased background noise on salmonids, available information suggests noise in the nearshore and offshore marine environment is a low to moderate threat to the recovery of listed salmonids.

MARINE AQUACULTURE

NOAA's Marine Aquaculture Policy (NOAA 2011) reaffirms that aquaculture is an important priority within NOAA's responsibilities to maintain healthy and productive marine and coastal ecosystems, protect special marine areas, rebuild overfished wild stocks, restore populations of endangered species, restore and conserve marine and coastal habitat, balance competing uses of the marine environment, create employment and business opportunities in coastal communities, and enable the production of safe, healthy, and sustainable seafood.

Concerns have been raised over environmental impacts of salmonid culture activities in nearshore or open ocean areas. Potential impacts include disease and parasite transmission, water quality impairment, and genetic interactions. The recovery of CC Chinook salmon and CCC and NC steelhead is unlikely to be hindered by current marine aquaculture activities because aside from the shellfish farming (*e.g.*, oysters and clams) occurring in estuaries, marine aquaculture is largely absent from the waters off the California coast where these three salmonids are assumed to spend most of their ocean residency. Furthermore, in 2003 commercial marine culture of salmonids was banned in California's jurisdictional waters (California FGC §15007), which extend three nautical miles out from shore. In Federal waters (between 3 and 200 nautical miles from the west coast), the process for obtaining a permit to carry out aquaculture is unwieldy and time consuming, and potentially discouraging to prospective investors (NOAA 2007). The National Sustainable Offshore Aquaculture Act of 2011 would retain NMFS' review of permit applications to ensure they do not jeopardize the continued existence of listed salmonids. While there are several proposed or operational offshore aquaculture facilities in southern California, opportunities are limited in Northern California due to more volatile ocean conditions. Given the low likelihood of any additional aquaculture operations off the Northern California coast in the next five years or more, and the expected close evaluation of any proposals by NMFS, EPA, and other agencies, culture of animals in nearshore and offshore marine areas is considered a low threat to the recovery of listed salmonids.

RECOVERY STRATEGIES FOR SALMONIDS IN MARINE HABITATS

In the marine environment, many threats to CC Chinook salmon and CCC and NC steelhead are difficult to predict, remove, or resolve (*e.g.*, El Nino, Pacific Decadal Oscillation, predation, oil spills, etc.). Effects of transportation, noise, shipping, and other similar actions on salmonids need more research for an improved understanding on potential threats and subsequent recovery strategies. Many of the aforementioned threats, such as oil spills and invasive species are being managed or addressed through existing authorities. Fisheries-related mortality of CC Chinook salmon in commercial and recreational fisheries, however, can be potentially controlled through improvements in monitoring, and resultant refinements in fisheries restrictions. In addition, habitat protection efforts such as marine protected areas, fishery exclusion zones, and marine habitat restoration are recovery strategies that implement ecosystem management approach.

As described above, CC Chinook salmon mortality in commercial and recreational fisheries is managed by limiting the preseason-predicted KRFC age-4 ocean harvest rate. O'Farrell *et al*. (2012) describes the existing strategies and evaluates the feasibility of implementing alternative strategies for ocean fisheries management relative to CC Chinook salmon. A major source of uncertainty in evaluating the effectiveness of KRFC-based management strategies on CC Chinook salmon is the origin of unmarked Chinook salmon. Improvements in monitoring and determining the origin and distribution of unmarked Chinook salmon populations contacted in fisheries could potentially lead to refinement of restrictions (*i.e*., area, season, gear, bag limit, *etc.*) that specifically reduce CC Chinook salmon mortality.

Marine Protected Areas

The State of California has recently implemented a series of underwater parks and reserves along the California coast as part of the Marine Life Protection Act (MLPA) of 1999. Under the MLPA, marine life reserves, which are an essential part of a marine protected areas system, "protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries" (California Fish and Game Code § 2852(f)). Fishing is closed or restricted in most marine protected areas (MPAs), which accounts for approximately 20 percent of state coastal waters (0-3 nautical miles from shore).[14] The public process to design and implement MPAs in California focused largely on protecting nearshore rocky benthic habitat that salmon may inhabit only sporadically in their life history. Many of the more popular salmon fishing areas are not expected to be within the boundaries of MPAs, and some MPAs where fishing is restricted make exceptions with regard to salmon fishing. Perhaps it is worth exploring the feasibility of a recovery strategy that places MPAs restricting salmon fishing at the

[14] The northern California MPAs went into effect on December 19, 2012, from the California-Oregon border to Point Arena (Mendocino County). The North Central California MPAs went into effect on May 1, 2010 from Alder Creek, near Point Arena (Mendocino County) to Pigeon Point (San Mateo County). The central California MPAs went into effect on September 27, 2007 from Pigeon Point (San Mateo County) to Point Conception (Santa Barbara County). For more details: http://www.dfg.ca.gov/marine/mpa/

mouths of rivers to protect essential or supporting populations. MPAs offer an ecosystem management tool that may benefit listed salmonid recovery, but the benefits have not been specifically quantified at this time.

CHINOOK SALMON AND STEELHEAD IN LARGE ESTUARIES

As part of recovery plan development for Federally-listed salmonids in the North Central California Coast Recovery (NCCC) Domain[15] (Figure 1), NOAA's National Marine Fisheries Service (NMFS) staff recognized the critical importance of the two largest estuaries in California, San Francisco and Humboldt Bays, for three listed species of salmonids: the Central California Coast (CCC) steelhead (*Onchorynchus mykiss*) DPS, in San Francisco Bay; and the Northern California (NC) steelhead (*O.mykiss*) DPS and California Coastal (CC) Chinook (*Onchorynchus tshawytscha*) ESU in Humboldt Bay.

Estuaries provide important nursery and rearing conditions for juvenile salmonids, particularly steelhead (MacFarlane and Norton 2002). Estuarine lagoons on California's central coast have been extensively documented as superior rearing habitat for steelhead and can contribute a disproportionate total number of returning adults compared to stream habitats when conditions are even marginally suitable (Smith 1990; Bond *et al.* 2008).

NMFS assessed current habitat conditions and future threats, and developed recovery strategies for San Francisco and Humboldt Bays as they relate to adult and juvenile salmonids utilizing estuarine habitat. Where conditions were identified as poor, or threats were identified as high or very high, recovery actions were developed to improve habitat conditions and/or reduce or abate the threats.

While similar to the analyses that were conducted for each essential or supporting population in freshwater habitats, these analyses for "bay specific" conditions and threats utilized a different set of parameters specific to the saline and brackish environment, and the life stages that utilize

[15] The recovery domain includes all coastal watersheds and the marine environment, including San Francisco and Humboldt Bays, from Redwood Creek in Humboldt County south to Soquel Creek in Santa Cruz County, California.

these habitats. Freshwater portions of the watersheds that drain into these estuaries were analyzed using a detailed set of spatial and ecological parameters described in Appendix D.

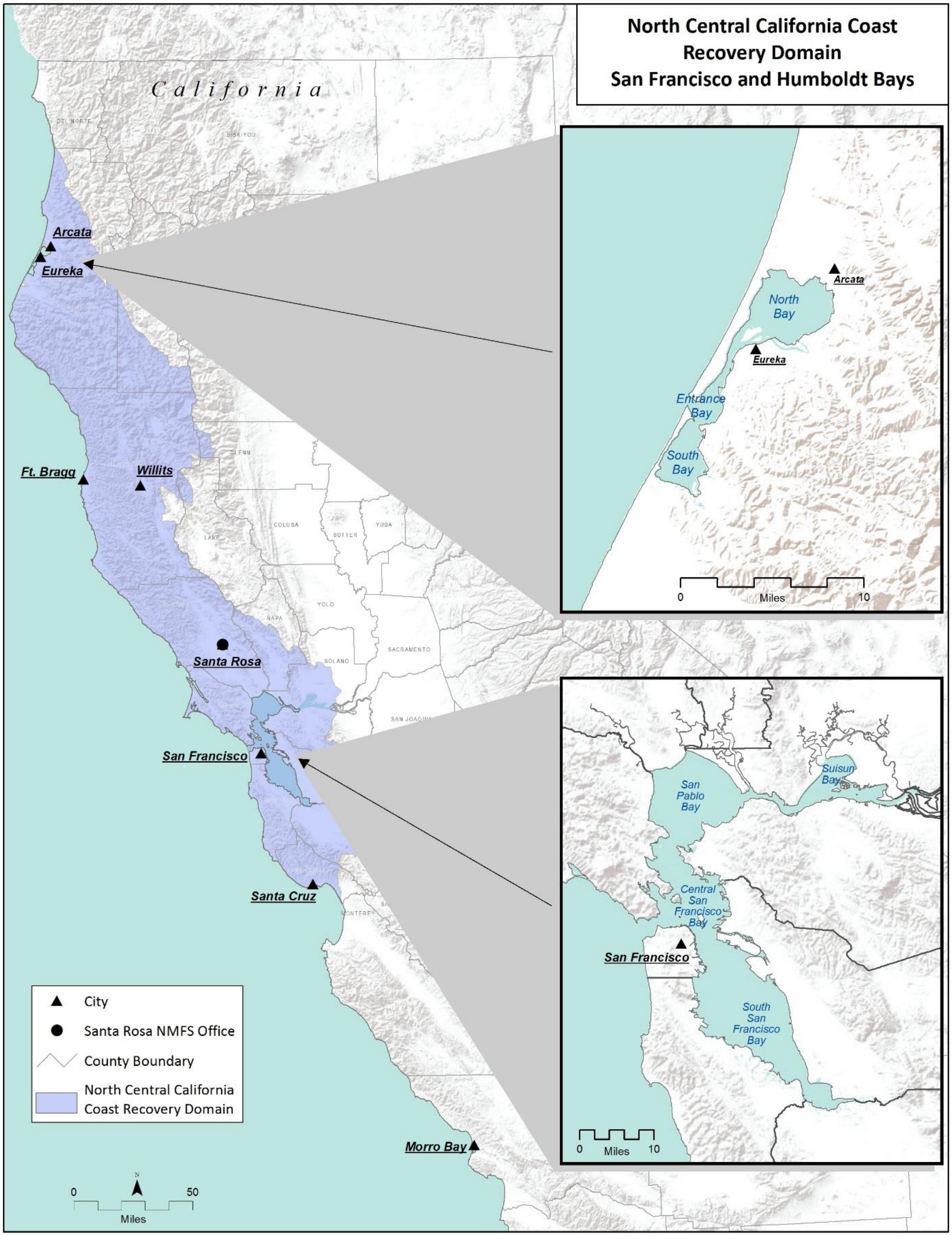

Figure 1. The North Central California Coast Recovery Domain, with San Francisco and Humboldt Bays highlighted.

"Current conditions" pertain to existing habitat and population conditions in San Francisco and Humboldt Bays that affect salmonid survival. Important conditions affecting CC Chinook salmon and CCC and NC steelhead include: (1) viability (as indicated by survival), (2) habitat modification (as indicated by habitat complexity, and residential or commercial development); (2) hydrology (as indicated by timing and extent of freshwater inflow); (3) water quality (as indicated by pollution); and (4) unimpeded migration (as indicated by barriers). These conditions are believed to have a large influence on juvenile and adult salmonid survival.

We defined the two life stages in the salmonid lifecycle that are influenced by the conditions in the estuarine environments. The life stages used in the analysis and their definitions are:

- Adults – Includes the period when adult salmonids enter San Francisco and Humboldt Bays from the Pacific Ocean and initiate their upstream migration toward spawning tributaries to the bays. We considered the migration period for adult salmonids[1] as November to May for the migration and post-spawn out-migration (*i.e.,* kelts returning to the ocean after spawning)
- Juvenile – Rearing juvenile salmon and steelhead includes pre-smoltification summer rearing of steelhead juveniles in tidally influenced areas, and estuarine residency where smolts may undergo additional growth and physiological changes as they adapt to the marine environment and migrate though the bays enroute to the Pacific Ocean. The smolting period is considered to occur from January to June. For steelhead, the summer rearing period may persist late into the fall months, or until the first rains occur.

We included in our assessment the tidal extent of San Francisco and Humboldt Bays, up to the "head of tide" in individual tributaries to the bays. In some cases, tidally influenced reaches were minimal, while in others, saline or brackish conditions continued some miles up into the watersheds (Figure 2).

[1] The purpose in defining discrete life stage periods is to assess habitat attributes during a representative time frame, not to encapsulate the full range of timing possibilities.

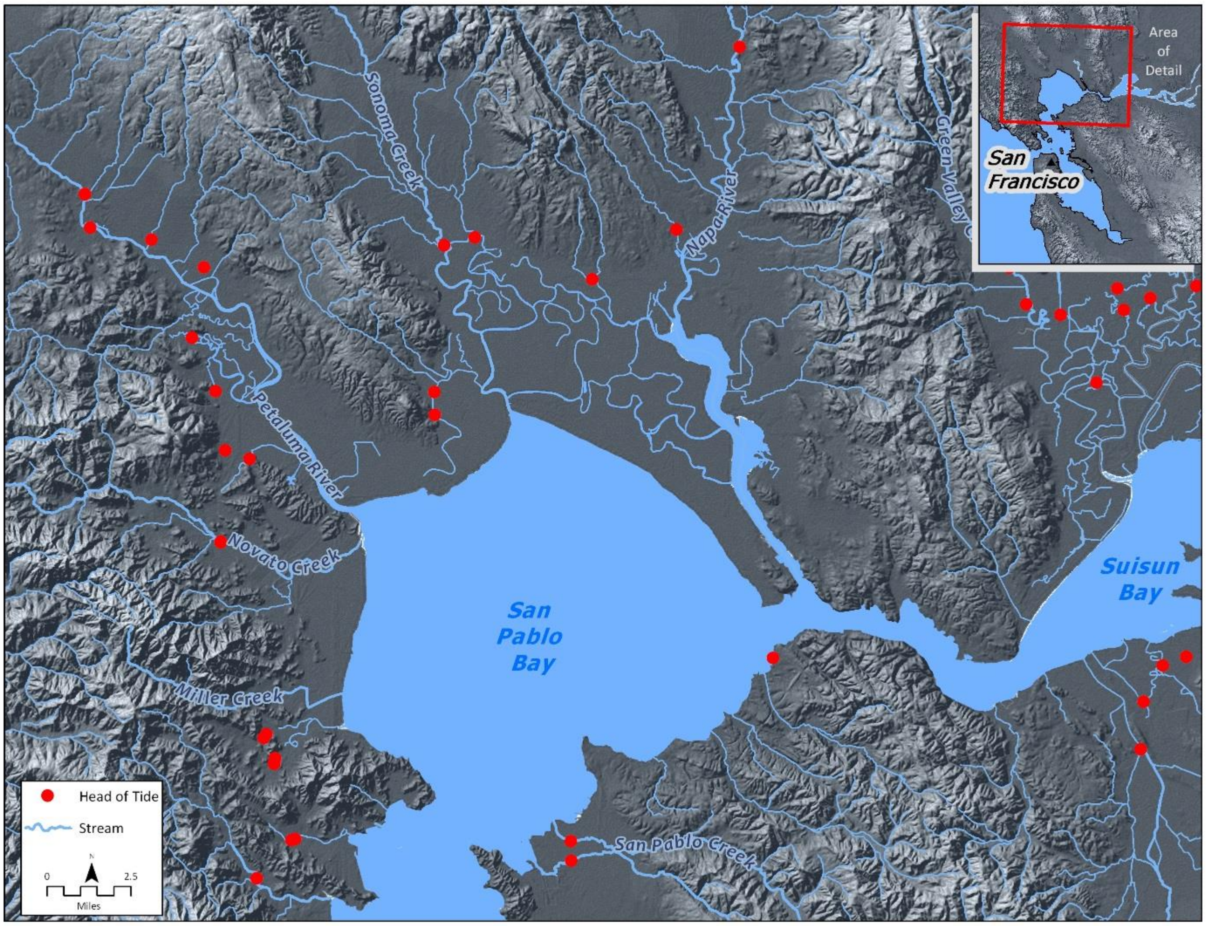

Figure 2. Example of a comparison of tidal extent in tributaries draining to northern San Francisco Bay.

As the head of tide shifts with tidal forces and freshwater inflows, the exact location varies across monthly and seasonal cycles. Assessing conditions up to the head of tide was consistent with Spence *et al*. (2008), which did not consider tidal reaches as habitat having "intrinsic potential" for supporting spawning and rearing. In spite of this, our analysis overlaps to some extent with the analyses conducted for individual watersheds, which analyzed conditions to the mouth of each watershed. Because we limited this analysis to those portions of the steelhead and salmon lifecycles which utilize the estuarine environment (adult and juvenile life stages), we considered this overlap conservative, and indicative of actual conditions experienced by steelhead and salmon.

SAN FRANCISCO BAY

San Francisco Bay is the largest and most highly modified estuary on the West Coast of the United States (Nichols *et al.* 1986). In addition to CCC steelhead, San Francisco Bay supports migration, and possibly rearing, for four salmonid species that migrate to tributaries of the Sacramento and San Joaquin Rivers. These four other salmonid species fall under the jurisdiction of the NMFS Central Valley Office. Cumulatively, San Francisco Bay is important for the recovery of 69 populations[16]; representing six diversity strata/groups[17], and four DPSs/ESUs[18] of anadromous salmonids. Our analysis was focused at assessing current conditions and future threats for CCC steelhead. Within the CCC steelhead DPS, NMFS identified 11 essential and 9 supporting populations that utilize San Francisco Bay.

For the purposes of the Coastal Multispecies Recovery Plan, San Francisco Bay includes all tidally influenced waters east of the Golden Gate, eastward to Chipps Island, where freshwater inflows mingle with salty waters in the Sacramento – San Joaquin Delta. The Bay includes subregions generally defined as: South Bay, Central Bay, San Pablo Bay, the Carquienez Straits, and Suisun Bay (Figure 3). It does not include waters east of Chipps Island, or the legally defined Sacramento – San Joaquin Delta.

[16] Combined total for all populations of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead, as well as that portion of the Central California Coast steelhead DPS that spawns in tributaries to the San Francisco Bay. Please see NMFS (2014), and this Recovery Plan for population and species lists.

[17] The six diversity strata include: Coastal San Francisco Bay and Interior San Francisco Bay (see this Recovery Plan); and the Central Valley groups of: Northwestern California, Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada (National Marine Fisheries Service 2014).

[18] The four DPSs/ESUs include: Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, Central Valley steelhead DPS, and Central California Coast steelhead DPS.

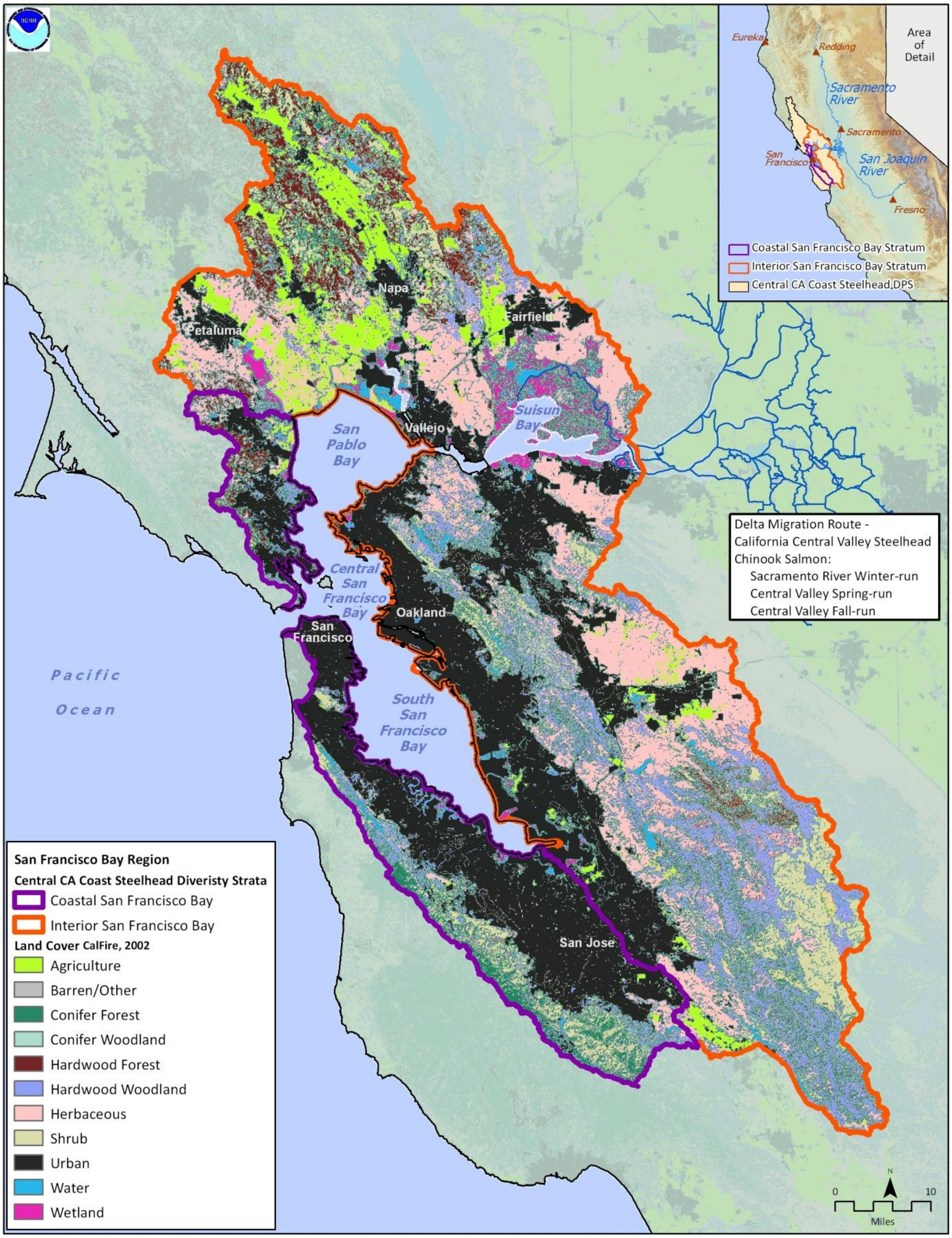

Figure 3. Boundaries, subregions, and major land use in the San Francisco Bay Area.

CURRENT CONDITIONS - SAN FRANCISCO BAY

Conditions critically important for CCC steelhead include, but are not limited to: include: (1) viability (as indicated by survival), (2) habitat modification (as indicated by habitat complexity, and residential or commercial development); (2) hydrology (as indicated by timing and extent of freshwater inflow); (3) water quality (as indicated by pollution); and, (4) unimpeded migration (as indicated by barriers). These conditions are believed to have a large influence on juvenile and adult salmonid survival. Information on the use of the San Francisco Bay by anadromous salmonids is limited. However, it is known that San Francisco Bay and its tributaries historically supported a robust salmonid fishery indicating the importance of the estuary to these populations.

ESTUARINE VIABILITY

Both historic and current distribution and abundance information for anadromous salmonids within San Francisco Bay is limited; however, available information indicates that abundance has likely declined precipitously, and spatial distribution of listed salmonids using the system have also likely decreased (Weitkamp *et al.* 1995; Busby *et al.* 1996; Myers *et al.* 1998). Juvenile and adult Chinook salmon and steelhead migrations through San Francisco Bay occur primarily in winter and spring. Research on hatchery Chinook salmon suggests salmonids show relatively rapid movement through the system, diverging little from their migratory pathways (MacFarlane and Norton 2002; Michel 2010) and a decrease in condition during their in-bay residence (MacFarlane and Norton 2002), and experience high rates of mortality (Michel 2010). Historically, however, extended residence times and broader habitat use for rearing purposes was likely common.

We considered direct mortality resulting from prop strikes, recreational fisheries, predation by pinnipeds such as harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*), and other potential sources of direct mortality for adult and juvenile salmonids. During a three-year study of tagged hatchery-origin smolts that were released within the upper Sacramento

River, Michel (2010) found that mortality was greatest through the San Francisco Bay portion of the migration. Considering the importance of estuarine habitats to the support of salmonids elsewhere (Smith 1990; Bond *et al*. 2008), we assessed viability as poor.

HABITAT MODIFICATION

Nearly one-third of the total area of the San Francisco Bay has been filled (California State Coastal Conservancy et al. 2010); approximately 79 percent of tidal marsh habitat has been lost; and approximately 90 percent of all tidal wetlands have been lost (California State Coastal Conservancy *et al.,* 2010), leading to a significant reduction in habitat available to support listed salmonids. NMFS considered habitat modifications related to fill (*e.g.,* loss of subtidal or shoreline habitat), shoreline development such as, levees, boat ramps and docks, seawalls, bridges and other infrastructure, and submerged pinnacle reduction (to facilitate shipping).

These habitat alterations, degradations, and losses are representative throughout the San Francisco Bay. Despite the loss and degradation of habitat, San Francisco Bay remains important habitat necessary for the conservation and recovery of listed salmonids. The Bay still provides habitat to a suite of birds, fish and invertebrates, and supports over 2,700 acres of eelgrass beds that serve as vital nursery areas and provide cover for young fish. Improved regulation, habitat protections, and restoration efforts are proving important for recovery of Bay habitats. Filling of Bay waters and wetlands is now highly regulated, and many agencies and groups have contributed to improved water quality and habitat restoration.

Healthy estuarine habitats are important for the support of both migration and rearing; functions critical to the maintenance of robust anadromous salmonid populations, including CCC steelhead. Habitat complexity provides shelter from high velocity water movements and predators, and supports prey populations. Significant losses (over 90%) of tidal and subtidal habitats such as wetland complexes and eelgrass beds have reduced complexity in San Francisco Bay (Goals Project 1999; California State Coastal Conservancy *et al.* 2010). Additionally, loss of habitat complexity has resulted from destruction or lowering of rocky reefs and pinnacles to facilitate traffic. Due to the loss of complex habitats we assessed this condition as poor.

Residential and Commercial Development

The land surface, soil, vegetation, and hydrology are all significantly altered in urban areas. The high degree of urban development surrounding San Francisco Bay influences storm flow quantity and timing, and is correlated highly with negative impacts such as pollutant run off. Major changes associated with increased urban land area include increased quantity and variety of pollutants in runoff, erratic hydrology due to increased impervious surface area and runoff conveyance, increased water temperatures due to loss of riparian vegetation and warming of surface runoff on exposed surfaces, and reduction in channel and habitat structure owing to sediment inputs, bank destabilization, channelization, and restricted interactions between the river and its land margin (Paul and Meyer 2001).

Anadromous fish have been shown to be adversely affected by urbanization. In studying the impacts of urbanization on stream habitat and fish across multiple spatial scales, Wang *et al*., (2001) found that relatively small amounts of urban land use in a watershed can lead to major changes in biota, and that there appears to be threshold values of urbanization beyond which degradation of biotic communities is rapid and dramatic (May *et al.* 1997; Wang *et al.* 2001). While many land uses have best management practices that can support or restore relatively healthy stream fish communities, relatively low levels of watershed urbanization inevitably lead to serious degradation of the fish community, and this condition was assessed as poor.

TIMING AND EXTENT OF FRESHWATER INFLOW

Reduced freshwater inflow (both to San Francisco Bay via the Sacramento – San Joaquin Delta, and on a smaller scale in each watershed around the Bay) has various effects, including increased salinity (*e.g*., saline water moves further upstream), and habitat alterations (such as those resulting in an increase in salt tolerant species). Measures of altered freshwater inflow include the large scale monitoring to track salinity levels (commonly referred to as X2) in the Sacramento – San Joaquin Delta, and estimates of alteration to the hydrograph in each watershed (including degrees of water storage and diversion, and known saltwater intrusion). Up to 70 percent of the freshwater flows that would naturally enter the San Francisco Bay through the San Joaquin and Sacramento River Systems are now diverted. This freshwater diversion has increased the net salinity of the Bay with a consequent alteration of the plant and animal species residing in many wetland communities (Steere and Schaefer 2001). Altered freshwater inflow may adversely affect migratory cues for adult steelhead. Intrusion of saline water upstream, resulting from reduced seasonal inputs of freshwater, may induce greater physiological stress on outmigrating juveniles. As a result of these significant and ongoing changes, we assessed this condition as poor.

WATER QUALITY

Optimal conditions for salmonids, their habitat and prey, include clean water free of pollutants. NMFS defines pollutants as substances (typically anthropogenic in origin) that cause acute, sub-lethal, or chronic effects to salmonids or their habitat. These include (but are not limited to) toxins known to impair watersheds, such as copper, diazinon, nutrients, mercury, polyaromatic hydrocarbons (PAHs), pathogens, pesticides, and polychlorinated biphenyls (PCBs), herbicides and algae. Mining activities occurring during the 19th century contributed to a substantial increase in sediment deposition in the lower portion of San Francisco Bay. Associated with this sediment were high levels of mercury, which was used to facilitate gold extraction. Pollution from historical and current sources results in poor water quality and degraded habitat conditions in San Francisco Bay. Depending on the exposure, toxic loading may result in acute mortality or sub lethal effects such as decreased fitness and condition over the long term. Salmonids are sensitive to toxic impairments, even at very low levels (Sandahl *et al.* 2004; Baldwin and Scholz 2005). For example, adult salmonids use olfactory cues to return to their natal streams to spawn, and low levels of copper may impair this ability (Baldwin and Scholz 2005).

We reviewed a variety of materials to assess water quality, including data from the California Regional Water Quality Control Boards, the U.S. Environmental Protection Agency, and other local and regional sources to inform our ratings of water quality limited segments for any toxins known or suspected of causing impairment to fish. We also reviewed scientific literature, and available watershed specific water quality reports. While water quality in San Francisco Bay has improved with the implementation of a variety of actions designed to prevent and reduce pollution, water quality is still too poor to support commercial aquaculture, or other beneficial uses. Therefore, we assessed this condition as poor.

IMPEDIMENTS TO MIGRATION

We evaluated the known presence of barriers that might impede or prevent adult immigration to spawning streams and juvenile emigration to the ocean. These included physical barriers such as dredge disposal plumes, thermal plumes from effluent, or deviations from normal electromagnetic fields known to impede or prevent migration. In San Francisco Bay, few consistent barriers were noted to impede migration and we assessed this condition as good .

THREATS - SAN FRANCISCO BAY

In this section, "threats" pertain to ongoing or future factors that impair conditions and decrease survival of CCC steelhead. Threats may result from currently active issues such as ongoing land uses or from issues likely to occur in the future (typically within ten years[19]), such as increased shoreline development. Many threats are driven by human activities, however naturally occurring events may also occur. These threats generally include, but are not limited to: habitat modification (invasive species; climate change and sea level rise; residential and commercial development; and water quality); disease, predation, and competition; transportation (dredging, noise, and shipping); aquaculture; and water diversion and impoundment.

[19] 10 year time period is part of the standard CAP methodology and protocol

HABITAT MODIFICATION

Completed, ongoing, or planned tidal and sub tidal restoration projects account for thousands of acres in both San Pablo Bay and the South Bay. The largest restoration project undertaken on the West Coast, the South Bay Salt Ponds, will restore thousands of acres of fully tidal habitat to former diked salt ponds. Another major restoration effort to restore extensive tidal marshes is ongoing in the Napa-Sonoma Salt Marsh.

Though restoration efforts are underway, additional development proposals with associated shoreline modification, benthic disturbance, and over water structures continue, and this threat is anticipated to persist into the future. Preventing future developments that have problematic habitat effects or otherwise minimizing their adverse effects will be vital to recovery. Additionally, it will be important to ensure that habitat restorations restore functional habitat processes, benefitting salmonids by supporting intact, highly functioning estuarine communities. This holistic approach to restoration will benefit listed salmonids and other listed and non-listed species alike.

Invasive Species

Invasive species include exotic non-natives that have naturalized within San Francisco Bay and have altered the benthic, water column, and/or wetland habitat functions. San Francisco Bay is the most invaded site on the west coast of the United States, with more than 175 exotic species established in its salt and brackish tidal waters (Cohen 2005). These species have come from many parts of the globe: gobies from Asia, freshwater fish primarily from the eastern United States, cordgrasses from the eastern United States and South America, clams and mussels from Asian, Atlantic and Mediterranean waters, snails from the North Atlantic, crabs from Europe, the eastern United States and China, isopods from Australia and New Zealand, and hydrozoan jellyfish from the Black Sea. These introductions have dramatically reduced native populations, altered habitat structure and trophic energy flows, and caused direct economic damage amounting to billions of dollars (Cohen 2005). Some introduced species, such as striped bass, prey directly on juvenile salmonids. As discussed below in Disease, Predation and

Competition, invasive species have adverse effects to both trophic webs and habitats, so this was assessed as a high threat.

Climate Change and Sea Level Rise

Climate change is categorized as a threat through its influence on estuarine productivity and sea level rise, and is discussed in more detail in Appendix B. Modeling of climate change impacts in California suggests that average summer air temperatures are expected to increase (Lindley *et al.* 2007). Heat waves are expected to occur more often, and heat wave temperatures are likely to be higher (Hayhoe *et al.* 2004). Total precipitation in California may decline; critically dry years may increase (Lindley *et al.* 2007; Schneider 2007). The Sierra Nevada snow pack is likely to decrease by as much as 70% to 90% by the end of this century under the highest emission scenarios modeled (Luers *et al.* 2006). Wildfires are expected to increase in frequency and magnitude by as much as 55% under the medium emissions scenarios modeled (Luers *et al*. 2006). Vegetative cover may also change, with decreases in evergreen conifer forest and increases in grasslands and mixed evergreen forests. The likely change in amount of rainfall in northern and central coastal California under various warming scenarios is less certain, although as noted above, total rainfall across the state is expected to decline. Many of these changes are likely to further degrade steelhead habitat by reducing freshwater inflows to San Francisco Bay or altering salinity gradients, for example.

Although it is uncertain precisely how climate change and sea level rise will affect the habitats in San Francisco Bay, it is likely that it will exacerbate existing poor water quality conditions (due to changes in runoff amounts and patterns), and poor habitat conditions (due to such responses as new levee and sea wall construction to combat sea level rise), thereby affecting listed salmonids within San Francisco Bay. Takekawa *et al.* (2013) estimated approximately 96% of surveyed tidal salt marsh habitat in San Francisco Bay would transition to mudflats by 2100 due to rising sea level. Therefore, this threat is expected to continue and worsen in the future. Adverse effects of current water operations (e.g. diversions and impoundments) are likely to increase in the event of climate change because more water may be impounded, and changes in snowpack and winter runoff patterns are expected. As a result, we assessed it as a high threat.

Residential and Commercial Development

The land surface, soil, vegetation, and hydrology are all significantly altered in urban areas. The high degree of urban development surrounding San Francisco Bay influences storm flow quantity and timing, and is correlated highly with negative impacts such as pollutant run off. Major changes associated with increased urban land area include increased quantity and variety of pollutants in runoff, erratic hydrology due to increased impervious surface area and runoff conveyance, increased water temperatures due to loss of riparian vegetation and warming of surface runoff on exposed surfaces, and reduction in channel and habitat structure owing to sediment inputs, bank destabilization, channelization, and restricted interactions between the river and its land margin (Paul and Meyer 2001).

Anadromous fish have been shown to be adversely affected by urbanization. In studying the impacts of urbanization on stream habitat and fish across multiple spatial scales, Wang *et al*., (2001) found that relatively small amounts of urban land use in a watershed can lead to major changes in biota, and that there appears to be threshold values of urbanization beyond which degradation of biotic communities is rapid and dramatic (May *et al.* 1997; Wang *et al.* 2001). While many land uses have best management practices that can support or restore relatively healthy stream fish communities, relatively low levels of watershed urbanization inevitably lead to serious degradation of the fish community.

Impacts from habitat modification and urban development tend to be widespread, tend to increase with increased density of human development, are typically non-point when compared to other land uses, and have impacts that, in many cases, are difficult to reverse. We used GIS interpretation of digital data layers to quantify the percentage of the San Francisco Bay in an urbanized state (Figures 2 and 3). Due to the extent and increasing intensity of the urban footprint, we assessed this a high threat.

Water Quality

Industrial, municipal, and agricultural wastes have been discharged either directly into the waters of San Francisco Bay or carried downstream to the estuary from sources upstream. Major historical point sources include agricultural wastes primarily from the Central Valley, residues leaching from abandoned mines, and municipal wastewater discharges. Sediment located within the ports of San Francisco, Oakland, and Richmond contains elevated levels of bioaccumulative anthropogenic contaminants, including polycyclic aromatic hydrocarbons (PAHs), polychorinate biphenols (PCBs), DDTs, mercury, dieldrin, chlordane, and dioxins/furans.

Wastewater discharges, thermal plumes, urban and agricultural storm water runoff, chemicals (such as PAHs, herbicides and pesticides, etc.), metals, sediments, and toxic spills are sources of pollution affecting water quality in San Francisco Bay. The US EPA and the State Water Resources Control Board list San Francisco Bay as an impaired waterbody for multiple pollutants, including chlordane, coliform bacteria, DDT, dieldrin, dioxin compounds, exotic species, mercury, PCBs, furan and selenium (SWRCB 2010). These pollutants degrade water quality, and may affect salmonids directly by increasing mortality or decreasing fitness or prey resources. As a result we assessed water quality as a high threat to recovery.

DISEASE, PREDATION AND COMPETITION

As noted above, invasive species in San Francisco Bay are pervasive and have a cascade of effects on the trophic web and biodynamics of the Bay functions. This threat is likely to continue into the future, as new species are introduced. Under this threat, NMFS considered invasive species such as Asian Clam species in the genus *Corbicula or Corbula,* which modify trophic webs by significantly reducing phytoplankton and zooplankton biomass (Kimmerer *et al.* 1994). Prior to this introduction, phytoplankton biomass in San Francisco Bay was approximately three times what it is today (Cloern 1996; Cloern and Jassby 2012). These species also modify the substrate. Additionally under this threat, we considered native and non-native piscivorous species such as Caspian Terns or Striped Bass. Piscivorous fish (*e.g.* striped bass) are known to respond to the arrival of hatchery trucks at release points. Large numbers of released fish may compete with CCC steelhead for prey resources. Prey resources take into account the availability of suitable prey and the health of food webs on which they depend. We assessed this threat as high.

TRANSPORTATION

Dredging

Under this threat, we considered maintenance dredging of shipping channels and boat basins. Dredging-related activities modify subtidal habitats – directly affecting 3.5% of the total area of the San Francisco Bay (NMFS 2010). While much of the Bay is dredged, implementation of protective dredging “work windows” (which limit dredging operations to periods of time when migrating listed salmonids are less likely to be present and exposed) minimizes effects to adults and juveniles. Dredging can impair water quality and habitat condition. Dredging activities may also cause direct mortality of juveniles (*e.g.* by entrainment in dredge intakes), and may impede their migration patterns.

Noise

As noted above in the section Noise in the Marine Environment, the west coast is one of the busiest routes for container shipping in the world, and the Port of Oakland is the fifth largest container port in the US. NMFS considered pile driving, ship traffic and other sources of underwater sound great enough to affect salmonids either behaviorally or physically. Protective work windows apply to many but not all of these activities. Juveniles may be more susceptible to barotrauma and may be exposed outside the work windows; therefore, noise may affect migration patterns and cause direct mortality.

Shipping

Shipping may cause direct mortality (*e.g.* prop strikes), as well as related impacts such as non-native species introductions (*e.g.* via ballast water releases, hull fouling) and oil, fuel or chemical spills, and noise. These impacts can impede migration patterns, and impair water quality or habitat conditions. Ongoing efforts to reduce associated effects of shipping act to reduce or minimize some shipping-related effects. These efforts include: spill response and containment plans, and ballast water regulations (to minimize invasive species introductions). However, since shipping and its associated dredging activities are expected to continue, and may increase, this threat is likely to continue into the future.

AQUACULTURE

As noted above under Marine Aquaculture, NOAA supports aquaculture for its potential to contribute to healthy stocks and recovery of listed species. In California, the California Department of Fish and Wildlife is the lead agency for leasing and permitting of marine aquaculture on state and private water bottoms in bays and estuaries, and ensures that marine resources and essential habitat are protected. In California, marine aquaculture for commercial purposes is currently limited to oysters, abalone, clams, and mussels. Potential threats include disease and parasite transmission, and water quality impairment. In some cases, shellfish aquaculture has improved conditions by enlarging eel grass beds and contributing to improved water quality. The recovery of CCC steelhead may be hindered by current aquaculture activities primarily from the shellfish farming (*e.g.,* oysters and clams) occurring in estuaries. There are currently no commercial aquaculture facilities in San Francisco Bay, and this is expected to remain a low threat for CCC steelhead.

WATER DIVERSION AND IMPOUNDMENT

NMFS considered water impoundments affecting San Francisco Bay (including both Central Valley reservoirs and local reservoirs), transfers (*e.g.,* Central Valley water released into Coyote Creek), and diversions or water withdrawals affecting freshwater inflows to San Francisco Bay. Water diversion and impoundments may impede migration (from loss of migratory cues), impair water quality (affecting salinity, timing, and duration of inflows), cause direct mortality (*e.g.,* by entrainment in muted tidal systems or pumps, *etc.*), and impair habitat condition (affecting salinity, changes in prey species, *etc.*). Efforts to improve flows to mimic a natural hydrograph (including the Freshwater Flows Resolutions in the San Francisco Bay-Delta

Estuary[20]), will help to improve this condition; however, as wide-scale water use (and overuse) associated with water diversions and impoundments is likely to persist within the tributaries to San Francisco Bay, this threat is likely to continue into the future. Therefore, we assessed water diversion and impoundment as a high threat to recovery.

RECOVERY STRATEGIES FOR CCC STEELHEAD IN SAN FRANCISCO BAY

In general, recovery strategies will focus on improving conditions and ameliorating stresses and threats discussed above, although strategies that address other conditions or threats may also be developed where their implementation is critical to restoring properly functioning habitat conditions within the watershed. Of primary importance is improving conditions that increase survival and decrease rates of mortality for CCC steelhead, particularly juveniles, as they migrate through the Bay. More detailed recommendations for specific recovery actions follow.

The recovery goals for San Francisco Bay are to provide adequate ecologically functional rearing and migration corridors for CCC steelhead utilizing the tributaries to the Bay, including the Sacramento and San Joaquin rivers. Recovery actions identify strategies that will contribute to protection and restoration practices imperative to the recovery of CCC steelhead.

Estuarine Viability: Improve Survival

CCC steelhead in San Francisco Bay would benefit from improved habitat conditions that support complex habitats for refugia and improved function of trophic webs. Healthy estuarine habitats are important for the support of critical life history transitions.

Habitat Modification: Improve Habitat Complexity and Implement Actions to Reduce Impacts of Urbanization

[20] For more information see: http://friendsofsfestuary.weebly.com/sf-estuary-resolutions.html

CCC steelhead in San Francisco Bay would benefit from improved habitat complexity and structure that would support improved food (prey) resources for both adults and juveniles and shelter for juveniles. Practices to improve habitat conditions include, but are not limited to, preservation of existing tidal and subtidal habitats, and restoration of habitats that have been degraded by past development and associated land uses. Targeted preservation and restoration efforts should focus on high priority areas. Several relevant efforts have been made to identify and prioritize these efforts, including the Goals Project (1999), the Subtidal Goals Project (California State Coastal Conservancy *et al.* 2010), and the San Francisco Estuary Watershed Evaluation (Becker *et al.* 2007). However, preservation and restoration efforts should proceed opportunistically as well, and should consider any as-yet unidentified opportunities in the San Francisco Bay that are shown to have particular value to the recovery of listed salmonids.

Timing and Extent of Freshwater Inflow

Improving and protecting freshwater inflows would restore a more natural salinity and reduce the alteration of plant and animal communities. Hydrology improvements in San Francisco Bay, specifically those that help to restore natural timing and magnitude of flows from its tributaries, would benefit both adults and juveniles. Opportunities to modify water operations and programs should be actively sought and implemented. These include partnering with Bay Area Water Agencies regarding freshwater flow resolutions[21].

Water Quality: Reduce Pollution

Water quality improvements in the San Francisco Bay would benefit both adults and juveniles. Existing sources of pollution and toxicity impairing water quality should be prioritized and addressed as part of a comprehensive improvement plan for San Francisco Bay. Both in-bay as well as watershed sources should be considered. Threats to water quality, such as oil or sewage spills, should receive increasing attention in planning and response.

[21] For more information see http://friendsofsfestuary.weebly.com/sf-estuary-resolutions.html

Habitat Modification: Manage Invasive Species, Climate Change, Urbanization and Water Quality to Prevent Adverse Effects

Decreasing/curtailing introductions of non-native species (via release of ballast water, hull-fouling, *etc.*), and improving habitat dominated by non-native species would benefit both adult and juvenile CCC steelhead in the San Francisco Bay region. Regulations that minimize the potential for non-native species introductions via release of ballast water should be aggressively implemented and enforced, and opportunities to improve native species compositions within the San Francisco Bay region should be actively sought and implemented.

As global climate change and sea level rise affect the sea level within San Francisco Bay, opportunities should be sought to minimize potential adverse habitat effects and infrastructure protection responses that degrade existing habitat and/or preclude potential future restorations. Where possible and appropriate, shoreline retreat and/or living shoreline methodologies may serve to both protect infrastructure and allow for, or increase, habitats that support listed salmonids.

Efforts to control urban runoff, restore more natural shorelines, and reduce impervious surfaces would benefit CCC steelhead in San Francisco Bay. While extensive restoration is planned or ongoing, planners should take into account the restoration of functional habitats. Such restoration planning would also improve water quality by reducing discharges of pollutants. Opportunities to modify water operations and programs should be actively sought and implemented. These include partnering with The Regional Water Quality Control Boards, the US EPA, and other Agencies regarding effluent discharges.

Disease, Predation and Competition: Manage Invasive Species

As noted above, management of invasive species that reduce available prey or predate directly on salmonids would reduce this threat. Considering releases of smaller groups of hatchery fish might reduce completion and predation from striped bass (*e.g*. a more natural release program).

Transportation: Limit Dredging, Reduce Impacts of Noise and Shipping

Minimizing suspension of contaminants and losses of prey associated with maintenance dredging, and minimizing release of pollutants and direct mortality would also benefit CCC steelhead.

HUMBOLDT BAY

Humboldt Bay includes all tidally influenced waters bounded by land to the east, and by northern and southern sand spits to the west. Humboldt Bay is split into three regions: the North Bay to the north of Samoa Bridge; the Entrance Bay from Samoa Bridge to South Jetty; and the South Bay, which is the remainder of the bay to the south.

Humboldt Bay (Figure 4) is important for the recovery of three species of salmonids, each with a population unit comprising of the major tributaries to Humboldt Bay (Jacoby Creek, Freshwater Creek, Elk River, and Salmon Creek). The Humboldt Bay tributaries Northern California (NC) steelhead population is in the Northern Coastal Diversity Stratum, and the California Coastal (CC) Chinook population is in the North Coastal Diversity Stratum. In addition, Humboldt Bay supports Southern Oregon/Northern California Coast coho salmon in the Southern Coastal Diversity Stratum.

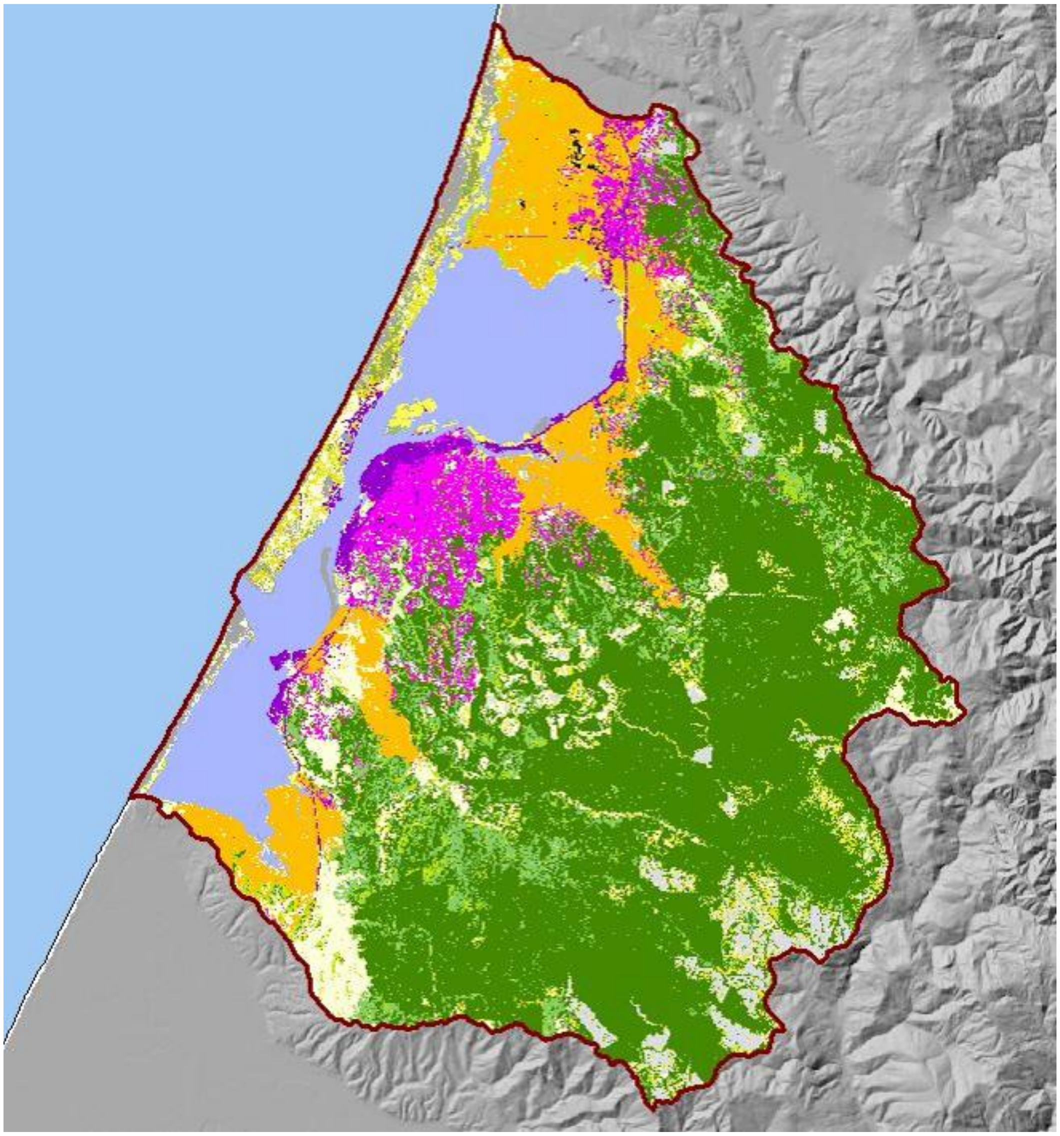

Figure 4: Major land use in the Eureka Plain hydrologic unit. Key: (green = commercial timber; orange = agricultural, and pink = urban/residential/industrial; KRIS 2006).

CURRENT CONDITIONS - HUMBOLDT BAY

ESTUARINE VIABILITY

Both historic and current distribution and abundance information for anadromous salmonids within Humboldt Bay is limited; however, available information indicates that abundance has likely declined precipitously, and spatial distribution of listed salmonids using the system has also likely decreased. Juvenile and adult Chinook salmon and steelhead migrations through Humboldt Bay occur primarily in fall, winter, and spring. Historically, however, extended residence times and broader habitat use for rearing purposes was likely common.

Considering the importance of estuarine habitats to the support of salmonids elsewhere (Smith 1990; Bond *et al*. 2008), and the current lack of complex estuarine habitats in Humboldt Bay, we assessed viability as poor.

HABITAT MODIFICATION

Since the 1800's, the physical habitat and habitat forming processes within Humboldt Bay, as well as in the tidally influenced portions of the bay's tributaries, have been altered by human activities associated with both upland and adjacent land use (agriculture, urban, residential, industrial) and construction and maintenance of transportation corridors (land and marine). In the tidally-influenced lower watersheds, the physical alteration and disconnection of backwater, side channel and floodplain habitats and subsequent inaccessibility to juvenile and adult salmonids due to passage barriers (culverts, tide gates), have reduced the quantity and quality of the tidal freshwater and estuarine rearing habitat. An estimated 85 percent of the original salt marsh and tidal slough habitat around Humboldt Bay is no longer available to salmonids (Shapiro and Associates 1980; Barnhart *et al.* 1992). The quantity and quality of existing rearing habitat was reduced from historic values due to construction of dikes and levees; draining, and filling of tidal sloughs for agricultural use; and fragmentation of tidal slough habitat by construction of the railroad and Highway 101.

Despite the loss and degradation of habitat, Humboldt Bay remains important habitat necessary for the conservation and recovery of listed salmonids. The Bay still provides habitat to a suite of birds, fish and invertebrates, and supports over 5,000 acres of eelgrass beds that serve as vital nursery areas and provide cover for young fish. Improved regulation, habitat protections, and restoration efforts are proving important for recovery of Humboldt Bay habitats. Filling of

Humboldt Bay waters and wetlands is now highly regulated, and many agencies and groups have contributed to improved water quality and habitat restoration.

Healthy estuarine habitats are important for the support of both migration and rearing; functions critical to the maintenance of robust anadromous salmonid populations, including CC Chinook, and NC steelhead. Information on the use of the Humboldt Bay by anadromous salmonids is limited. However, rearing Chinook salmon are known to favor the tidal slough channels and rearing steelhead are known to favor the estuary-stream ecotone. In addition, Humboldt Bay and its tributaries historically supported a robust salmonid fishery indicating the importance of the estuary to these populations. Habitat complexity provides shelter from high velocity water movements and predators, and supports prey populations.

Residential and Commercial Development

The Humboldt Bay watershed is comprised of approximately 8% residential and commercial development. The land surface, soil, vegetation, and hydrology are all significantly altered in urban areas. Urban development surrounding Humboldt Bay (i.e., cities of Eureka and Arcata) influences storm flow quantity and timing, and is correlated highly with negative impacts such as pollutant run off. Changes associated with increased urban land area include increased quantity and variety of pollutants in runoff, erratic hydrology due to increased impervious surface area and runoff conveyance, increased water temperatures due to loss of riparian vegetation and warming of surface runoff on exposed surfaces, and reduction in channel and habitat structure owing to sediment inputs, bank destabilization, channelization, and restricted interactions between the river and its land margin (Allen 2004).

Anadromous fish are adversely affected by urbanization. In studying the impacts of urbanization on stream habitat and fish across multiple spatial scales, Wang *et al*., (2001) found that relatively small amounts of urban land use in a watershed can lead to major changes in biota, and that there appears to be threshold values of urbanization beyond which degradation of biotic communities is rapid and dramatic (May et al. 1997, Wang *et al.* 2000). While many land uses have best management practices that can support or restore relatively healthy stream fish communities, relatively low levels of watershed urbanization inevitably lead to degradation of the fish community. Due to the current amount of development, this condition was assessed as poor.

TIMING AND EXTENT OF FRESHWATER INFLOW

Impervious surfaces in urbanized areas have resulted in increased surface runoff and therefore higher peak flows and altered timing of freshwater entering the Bay. Inboard ditches collect and channelize surface runoff and subsurface flows and efficiently route water to streams resulting in higher, earlier, and more frequent peak flows. Because most residents in the Bay's watershed receive their water supply from the local Water District (which uses water from the Mad River), the amount of freshwater inflow is affected by relatively few residential water diversions. We assessed this condition to be fair.

WATER QUALITY

Optimal conditions for salmonids, their habitat and prey, include clean water free of pollutants. NMFS defined pollutants as substances (typically anthropogenic in origin) that may cause acute, sub-lethal, or chronic effects to salmonids or their habitat. These include (but are not limited to) toxins known to impair watersheds, such as copper, diazinon, nutrients, mercury, polyaromatic hydrocarbons (PAHs), pathogens, pesticides, polychlorinated biphenyls (PCBs), herbicides and algae. Pollution from historical and current sources results in degraded water quality and habitat conditions within Humboldt Bay. Depending on the exposure, toxic loading may result in acute mortality or sub lethal effects such as decreased fitness and condition over the long term.

We evaluated water quality and the presence of toxins known to affect adult salmonids, from acute effects, sub-lethal or chronic effects, and no acute or chronic effects. All target life stages depend on good water quality, and the water quality attribute is impaired when pollutants, toxins or other contaminants are present at levels which adversely affect one or more salmonid life stages, their habitat or prey. Salmonids are sensitive to toxic impairments, even at very low levels (Sandahl *et al.* 2004; Baldwin and Scholz 2005). For example, adult salmonids use olfactory cues to return to their natal streams to spawn, and low levels of copper has been show to impair this ability (Baldwin and Scholz 2005).

We reviewed a variety of materials to assess water quality, including data from the California Regional Water Quality Control Boards, the U.S. Environmental Protection Agency, and other local and regional sources to inform our ratings of water quality limited segments for any toxins known or suspected of causing impairment to fish. We also reviewed scientific literature, and available watershed specific water quality reports. Humboldt Bay was listed as impaired by polychlorinated biphenyls (PCBs) under Section 303(d) of the Clean Water Act in 2002, based on levels of PCBs found in fish tissue. Dioxin, heavy metals, petroleum products, and other contaminants persist in areas where they were used in the past, and continue to enter Humboldt Bay through storm water and ground water discharges. The overall effect of toxins on Humboldt Bay salmonids is unknown, but as a result of known toxins in the Bay we assessed this condition as fair.

IMPEDIMENTS TO MIGRATION

We evaluated the known presence of barriers that might impede or prevent adult immigration to spawning streams and juvenile emigration to the ocean. These included physical barriers such as dredge disposal plumes, thermal plumes from effluent, or deviations from normal electromagnetic fields known to impede or prevent migration. Several tidegates limit access to tidal slough channels in Humboldt Bay. Few other consistent impediments to migration exist in Humboldt Bay; therefore we assessed migration to be in good condition.

THREATS - HUMBOLDT BAY

In this section, "threats" pertain to ongoing or future factors that affect CC Chinook and NC steelhead estuarine survival. Threats may result from currently active issues such as ongoing land uses or from issues likely to occur in the future (usually within ten years), such as increased shoreline development. Threats are expected to impair conditions supporting salmonid habitat into the future. Many threats are driven by human activities, however naturally occurring events may also threaten the species. Climate change is categorized as a threat through its influence on estuarine productivity and sea level rise, and is discussed in more detail in Appendix B. These threats generally include, but are not limited to: habitat modification (climate change and sea level rise; disease, predation, and competition; residential and commercial development; and water quality); transportation (dredging, noise, and shipping); aquaculture; and water diversion and impoundment.

HABITAT MODIFICATION

Completed, ongoing, or planned tidal and sub tidal restoration projects account for hundreds of acres in both the North and South sub-bays. Many completed restoration projects have leveraged opportunities on public lands, as well as provided incentives for participation by private landowners. For example, the City of Arcata Baylands and McDaniel Slough Restoration and Enhancement Projects restored and enhanced wetland, riparian and stream habitat adjacent to the Humboldt Bay National Wildlife Refuge, the Arcata Marsh and Wildlife Sanctuary, the Mad River Slough Wildlife Area and Jacoby Creek Land Trust holdings, thereby establishing a continuous, protected habitat area of over 1,300 acres.

Though restoration efforts are underway, additional development proposals with associated shoreline modification, benthic disturbance, and over water structures continue, and this threat is anticipated to persist into the future. Preventing future developments that have problematic habitat effects or otherwise minimizing their adverse effects will be vital to recovery. Additionally, it will be important to ensure that habitat restorations restore functional habitat processes, benefitting salmonids by supporting intact, highly functioning estuarine communities. This holistic approach to restoration will benefit listed salmonids and other listed and non-listed species alike.

Invasive Species

Invasive species take into account aquatic and wetland species that are exotic non-natives, and are naturalized within the habitat and have adversely altered the benthic, water column, and/or wetland habitat functions. In Humboldt Bay many of the fouling organisms present within the Eureka boat basin and the Woodley Island Marina (WIM) are non-indigenous species, introduced either in ballast water of vessels or attached to vessel hulls (Ruiz *et al.* 2000; Boyd *et al*. 2002). The concrete piers and pilings of the WIM have been colonized by non-native species of amphipods *Corophium acherusicum* and *C. insidiosum*. Non-native dwarf eel grass *Zostera japonica* competes with native eelgrass in the Bay, and the non-native denseflower cordgrass *Spartina densiflora* has reduced the area of mudflats by colonizing their upper limits. We assessed invasive species as a moderate threat.

Climate Change and Sea Level Rise

Modeling of climate change impacts in California suggests that average summer air temperatures are expected to increase (Lindley *et al*. 2007). Heat waves are expected to occur more often, and heat wave temperatures are likely to be higher (Hayhoe *et al*. 2004). Total precipitation in California may decline; critically dry years may increase (Lindley *et al*. 2007, Schneider 2007). The likely change in amount of rainfall in northern California under various warming scenarios is less certain, although as noted above, total rainfall across the state is expected to decline. For the California north coast, some models show large increases (75% to 200%), while other models show decreases of 15% to 30% (Hayhoe *et al*. 2004). Many of these changes are likely to further degrade steelhead habitat by reducing freshwater inflows to Humboldt Bay or altering salinity gradients, for example.

The vulnerability of estuarine habitat to sea level rise is high. Rising sea level will likely reduce the quality and quantity of tidal-wetland rearing habitat in Humboldt Bay (e.g., increase salt marsh and reduce intertidal flats (Galbraith *et al.* 2002). Wetlands could migrate inland with rising sea level, but there are currently few areas without levees where this could occur.

The tidally influenced habitat of the Humboldt Bay watershed is highly vulnerable to sea-level rise due the location of urban and residential developments, existing land use and public infrastructure (CNRA 2009; Heberger *et al.* 2009). Estuarine habitat migration with sea level rise will ultimately be linked to decisions and subsequent implementation of actions to protect existing public sector infrastructure, including transportation (e.g., highway, airport, port facilities); energy (e.g., power plant, natural gas pipeline, transmission lines); water (e.g., Humboldt Bay Municipal Water District water main, city of Arcata and Eureka wastewater treatment facilities) and public and private land use (e.g., city of Arcata and Eureka; Humboldt Bay National Wildlife Refuge, Humboldt Bay Reclamation District; Humboldt Bay Harbor, Recreation, and Conservation District). As a result, we assessed climate change and sea level rise as a high threat.

Residential and Commercial Development

The land surface, soil, vegetation, and hydrology are all significantly altered in urban areas. The urban development surrounding Humboldt Bay (i.e., cities of Eureka and Arcata) influences storm flow quantity and timing, and is correlated highly with negative impacts such as pollutant run off. Future development may degrade existing tidally influenced habitat and limit the value of existing or planned restoration projects. Of particular concern is the potential subdivision of timberlands for residential use, which would result in an expanded network of roads and impervious surfaces.

Impacts from habitat modification and urban development tend to be widespread, tend to increase with increased density of human development, are typically non-point when compared to other land uses, and have impacts that, in many cases, are difficult to reverse. We used a GIS interpretation of digital data layers to quantify the percentage of the watershed in an urbanized state (Figure 4). Due to the extent and likely moderate future increase of the urban footprint, we assessed this as a moderate threat.

Water Quality

Industrial, municipal, and agricultural wastes have been discharged either directly into the waters of Humboldt Bay or carried downstream to the estuary from sources upstream. Major pollution sources include agricultural wastes primarily from diked former tidelands, urban runoff, and municipal wastewater discharges.

As described above, Humboldt Bay was listed as impaired by PCBs under Section 303(d) of the Clean Water Act in 2002, based on levels of PCBs found in fish tissue. Dioxin, heavy metals, petroleum products, and other contaminants persist in areas where they were used in the past, and continue to enter Humboldt Bay through storm water and ground water discharges. As a result we assessed water quality as a moderate threat.

DISEASE, PREDATION AND COMPETITION

As noted above, invasive species in Humboldt Bay are pervasive and may have effects on the trophic web and biodynamics of the Bay functions. This threat is likely to continue into the future as new species are introduced. Therefore, we assessed disease, predation, and competition as a moderate threat.

TRANSPORTATION

Dredging

Under this threat, we considered maintenance dredging of shipping channels and boat basins. Annual maintenance dredging of the interior Federal Navigation Channels in Humboldt Bay, as well as the bar and entrance channels, increases turbidity and turbulence, and thereby reduces the rearing and migratory corridor functions at various locations from March through May. Boat basins in the bay are dredged on an as-needed basis. Dredging activities may cause direct mortality of juveniles (e.g. by entrainment in dredge intakes), and may impede their migration patterns.

Noise

NMFS considered pile driving, ship traffic and other sources of underwater sound great enough to affect salmonids either behaviorally or physically. Protective work windows and noise minimization measures apply to many but not all of these activities. For adults, noise was not assessed because the established work windows are considered adequately protective of this life stage. Juveniles may be more susceptible to barotrauma and may be exposed outside the work windows; therefore, noise may affect migration patterns and cause direct mortality.

Shipping

Shipping may cause direct mortality (e.g. propeller strikes), as well as related impacts such as non-native species introductions (e.g. via ballast water releases, hull fouling) and oil, fuel or chemical spills, and noise. These impacts can impede migration patterns, and impair water quality or habitat conditions. This threat is likely to continue and may increase into the future if development increases in the harbor.

Due to the ongoing potential effects from dredging, noise, and shipping, we assessed transportation as a moderate threat.

AQUACULTURE

As noted above under Marine Aquaculture, NOAA supports aquaculture for its potential to contribute to healthy stocks and recovery of listed species. In California, the California Department of Fish and Wildlife is the lead agency for leasing and permitting of marine aquaculture on state and private water bottoms in bays and estuaries, and ensures that marine resources and essential habitat are protected. In California, marine aquaculture for commercial purposes is currently limited to oysters, abalone, clams, and mussels. Potential threats include disease and parasite transmission, water quality impairment, genetic interactions, and habitat degradation. Currently, approximately 300 acres of Humboldt Bay is utilized for culture of non-native oysters, and significant expansion of oyster culture is currently proposed. Potential impacts of particular concern from oyster culture in Humboldt Bay are diminished carrying capacity (e.g., food web dynamics) and reductions in native eelgrass habitat. The effects of shellfish culture on CC Chinook salmon and NC steelhead in Humboldt Bay are poorly understood. Due to the uncertainty regarding potential negative effects and the proposed expansion of shellfish culture in Humboldt Bay, we assessed aquaculture as a moderate threat.

WATER DIVERSION AND IMPOUNDMENT

NMFS considered water impoundments, water withdrawals, and water operations affecting freshwater inflows to Humboldt Bay. There are no dams in the Humboldt Bay watershed, but according to the Department of Water Resources database (http://www.waterboards.ca.gov/ ewrims/), there are 53 appropriative water rights and diversion points in the Eureka Plain, although not all are active. However, not all water diversions are registered with DWR. Riparian residential and agricultural uses can comprise significant amounts of water especially during low flow periods. Although water users are generally required to comply with CDFW streambed alteration program requirements (California Fish and Game Code § 1600 *et seq.*), this has not been common practice for small agriculture and residential withdrawals. Water withdrawals in the summer months can reduce tidal freshwater habitat available for rearing salmonids. We assessed water diversion and impoundment as a moderate threat.

RECOVERY STRATEGIES FOR CC CHINOOK AND NC STEELHEAD IN HUMBOLDT BAY

In general, recovery strategies will focus on improving conditions and ameliorating stresses and threats discussed above, although strategies that address other conditions or threats may also be developed where their implementation is critical to restoring properly functioning habitat conditions within the watershed. Of primary importance is improving conditions that increase survival and decrease rates of mortality for these listed salmonids, particularly juveniles, as they migrate through the Bay. More detailed recommendations for specific recovery actions follow.

The recovery goals for Humboldt Bay are to provide adequate ecologically functional rearing and migration corridors for these listed salmonids utilizing the tributaries to the Bay. Recovery actions identify strategies that will contribute to protection and restoration practices imperative to the recovery of these listed salmonids.

Habitat Modification: Improve Habitat Complexity

Listed salmonids in Humboldt Bay would benefit from improved habitat complexity and structure that would support improved food (prey) resources for both adults and juveniles and shelter for juveniles. Practices to improve habitat conditions include, but are not limited to, preservation of existing tidal and subtidal habitats, restoration of habitats that have been degraded by past development and associated land uses, and improved access to tidal channels behind tidegates. Targeted preservation and restoration efforts should focus on high priority areas. Preservation and restoration efforts should proceed opportunistically as well, and should consider any as-yet unidentified opportunities in Humboldt Bay that are shown to have particular value to the recovery of these listed salmonids.

Water Quality: Reduce Pollution

Water quality improvements in Humboldt Bay would benefit both adults and juveniles. Existing sources of pollution and toxicity impairing water quality should be prioritized and addressed as part of a comprehensive improvement plan for Humboldt Bay. Both in-bay as well as watershed sources should be considered. Threats to water quality, such as oil or sewage spills, should receive increasing attention in planning and response.

Habitat Modification: Manage Invasive Species, Climate Change, Urbanization and Water Quality to Prevent Adverse Effects

Improving habitat dominated by non-native vegetation would benefit both adult and juvenile salmonids in Humboldt Bay. Removal and suppression efforts for invasive dwarf eelgrass and cordgrass should be continued and increased in order to provide more productive salmonid habitat.

As global climate change and sea level rise affect the sea level within Humboldt Bay, opportunities should be sought to minimize potential adverse habitat effects and infrastructure protection responses that degrade existing habitat and/or preclude potential future restorations. Where possible and appropriate, shoreline retreat and/or living shoreline methodologies may serve to both protect infrastructure and allow for, or increase, habitats that support these listed salmonids.

Efforts to control urban runoff, restore more natural shorelines, and reduce impervious surfaces would benefit these listed salmonids in Humboldt Bay. While extensive restoration is planned or ongoing, planners should take into account the restoration of functional habitats. Such restoration planning would also improve water quality by reducing discharges of pollutants. Opportunities to modify water operations and programs should be actively sought and implemented. These include partnering with the Regional Water Quality Control Boards, the US EPA, and other agencies regarding effluent discharges.

Transportation: Limit Dredging, Reduce Impacts of Noise and Shipping

Minimizing suspension of contaminants and losses of prey associated with maintenance dredging, and minimizing release of pollutants and direct mortality would also benefit these listed salmonids.

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